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Health and Environmental Effects of Coal Gasification and Liquefaction Technologies A Workshop Summary and Panel Reports

MITRE Corp., McLean, VA

Prepared for

Federal Interagency Committee on the Health and Environmental Effects of Energy Technologies, McLean, VA

May 79

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Health and Environmental Effects of Coal Gasification and Liquefaction Technologies

**A Workshop Summary
and Panel Reports**

for the

**Federal Interagency Committee on
the Health and Environmental Effects
of Energy Technologies**

Department of Energy

Department of Health,
Education, and Welfare

Environmental
Protection Agency

Executive Secretariat
The MITRE Corporation/Metrek Division
McLean, Virginia 22102

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This report responds to President Carter's directive to identify health and environmental problems associated with advanced energy technologies. The report contains a presentation of the highlights of the issues and the detailed information requirements identified by panels of a workshop held in Leesburg, Virginia in August 1978 to address the health and environmental effects of coal gasification and liquefaction technologies.

The purposes of the workshop were to: 1) assemble multidisciplines of biomedical and environmental scientists to address current developments in these technologies, 2) review and identify specific health and environmental issues and problems associated with their development and commercialization, and 3) consider research strategies required to address them and to identify requisite information needs for resolving uncertainties of assessing the relevant impacts of coal gasification and liquefaction technologies.

The six panels of the workshop were: occupational and public health and safety; air quality; water quality, water quantity, and aquatic ecology; terrestrial effects; ambient measurement and monitoring; and source characterization. Panel reports containing specific information on environmental and health effects, information requirements, and detailed research statements are included in this report.

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Organic Chemistry
Chemical Chemistry
Air Quality
Water Quality

Gasification
Liquefaction

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Coal Cleaning
Energy Extraction
Synthetic Fuels
Advanced Systems

Processes and Effects
Transport Processes
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Character Measurement & Monitoring

Health Effects
Integrated Assessment
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Extraction
Processing

Conversion
Utilization
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Health and Environmental Effects of Coal Gasification and Liquefaction Technologies

**A Workshop Summary
and Panel Reports**

for the

**Federal Interagency Committee on
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Edited by:
Richard Brown
and
Alice Witter

May 1979

Prepared by:
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Metrek Division

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The MITRE Corporation/Metrek Division
1820 Dolley Madison Boulevard
McLean, Virginia 22102

FOREWORD

In his 1977 Environmental Message, President Carter directed the Secretary of Energy, the Secretary of Health, Education, and Welfare, and the Administrator of the Environmental Protection Agency to establish a joint program to identify the health and environmental problems associated with advanced energy technologies and to review the adequacy of present research programs. In response to the President's directive, representatives of the three agencies formed the Federal Interagency Committee on the Health and Environmental Effects of Energy Technologies. The MITRE Corporation, Metrek Division, is the Executive Secretariat for the Committee.

The goals of this Committee are to review and identify specific health and environmental issues and potential problems associated with the development and commercialization of conventional and advanced energy technologies, to identify the research information required to resolve the uncertainties of assessing relevant impacts, to specify research projects to provide such information, and to review the adequacy of current Federal research with respect to these projects. To attain these goals, the Committee is sponsoring a series of workshops, establishing working groups, and initiating other approaches to address the health and environmental consequences of specific energy technologies.

This report is the result of a workshop to address the health and environmental effects of coal gasification and liquefaction technologies held in Leesburg, Virginia, from August 20 to 25, 1978, chaired by William Frietsch of the Environmental Protection Agency on behalf of the Interagency Committee. MITRE technical support for workshop activities and preparation of this report has been provided under joint funding by the Committee through a Department of Energy contract mechanism (DEAC-01-79-EV10018), MITRE project number 1686K.

The purposes of the workshop were:

- to assemble biomedical and environmental scientists, representative of a broad range of disciplines, to address current developments in coal gasification and liquefaction technologies
- to review and identify specific health and environmental issues and problems associated with the development and commercialization of these technologies

- to consider the research strategies required to address them and to identify the requisite research information needs, expressed via detailed task statements, for resolving the uncertainties of assessing the relevant impacts of coal gasification and liquefaction technologies.

Throughout the workshop, attendees participated in six panels: occupational and public health and safety; air quality; water quality, water quantity, and aquatic ecology; terrestrial effects; ambient measurement and monitoring; and source characterization. This report contains a presentation of the highlights of the issues considered by the panels and the panel reports, which contain specific information on environmental and health effects, information requirements, and detailed research statements. Lists of participants and support staff are provided in the Appendix.

This report on coal gasification and liquefaction technologies responds to the first part of the President's directive--to identify health and environmental problems. The requisite research information needs associated with these problems will be compared with present Federal research programs in another report, a synthetic fuels summary, which will relate the priority of health and environmental research requirements of both oil shale and coal gasification and liquefaction technologies to ongoing research. The results of these reports and other products of the Interagency Committee should provide a basis for strengthening the Federal program for ensuring safe and timely development of our energy resources.

THE FEDERAL INTERAGENCY COMMITTEE
ON THE HEALTH AND ENVIRONMENTAL
EFFECTS OF ENERGY TECHNOLOGIES

WORKSHOP ON THE
HEALTH AND ENVIRONMENTAL EFFECTS OF
COAL GASIFICATION AND LIQUEFACTION TECHNOLOGIES

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*Committee Membership as of August 1978.

HEALTH AND ENVIRONMENTAL EFFECTS OF COAL GASIFICATION AND LIQUEFACTION TECHNOLOGIES

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HEALTH AND ENVIRONMENTAL EFFECTS
OF COAL GASIFICATION AND LIQUEFACTION TECHNOLOGIES

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INTRODUCTION[*]

The Resource

Coal is a carbonaceous, nonhomogeneous, highly variable fossilized material derived from decayed plant material (peat), which was subjected to a variety of microbiological, geophysical, and geochemical conditions. These result in considerable variation in the composition, structure, and uses of coal.

Coal is ranked according to its content of moisture and heat potential (Btu/lb). In general, a higher rank implies an increase in carbon and oxygen content, and a decrease in volatile and moisture content. Rank varies from the low-rank lignite through subbituminous and bituminous to high-rank anthracite. The distribution of coals in the conterminous United States is shown in Figure 1.

U.S. coal reserves are estimated to amount to more than 80 percent of the total fossil fuels available and are sufficient to support production of significant volumes of synthetic fuels. The 230 billion tons of coal that are considered minable by existing methods on a reasonably economic basis, could supply the country's estimated requirements for solid, liquid, and gaseous fuels for decades.

The Technologies

Coal gasification and liquefaction consist of two basic steps: the reduction of heavy hydrocarbons into lighter ones and the

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[*] Adapted from: Federal Interagency Committee on the Health and Environmental Effects of Energy Technologies. Background Material for the Workshop on Health and Environmental Effects of Coal Gasification and Liquefaction Technologies. July, 1978. Available as PB 296 708 from the National Technical Information Service.

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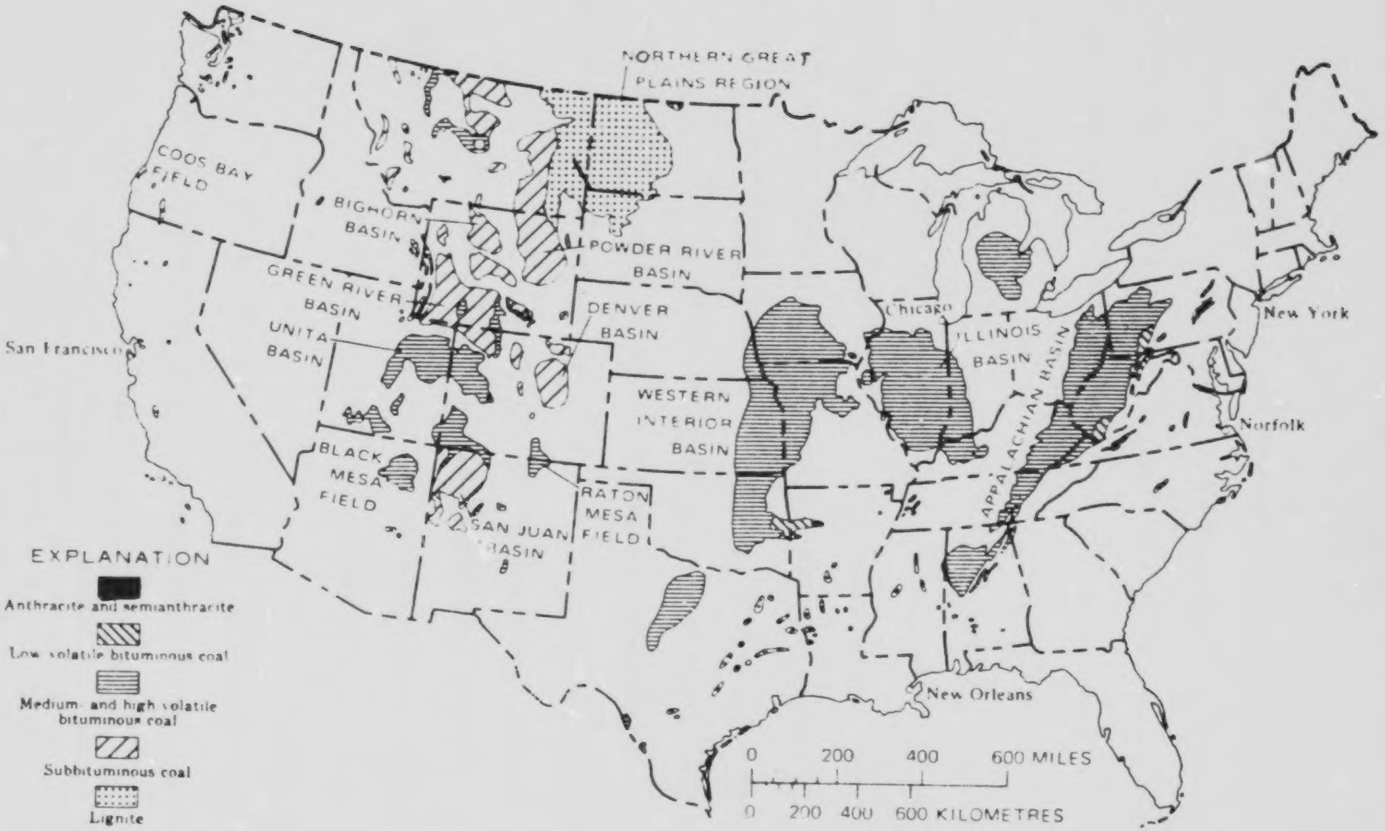
NORTHERN GREAT PLAINS REGION
COOS BAY FIELD
BIGHORN BASIN
POWDER RIVER BASIN
GREEN RIVER BASIN
DENVER BASIN
UNITA BASIN
WESTERN INTERIOR BASIN
BLACK MESA FIELD
RATON MESA FIELD
SAN JUAN BASIN
ILLINOIS BASIN
APPALACHIAN BASIN
Chicago
New York
Norfolk
New Orleans
San Francisco
EXPLANATION
Anthracite and semianthracite
Low volatile bituminous coal
Medium- and high volatile bituminous coal
Subbituminous coal
Lignite
0
200
400
600 MILES
0
200
400
600 KILOMETRES

FIGURE 1
COAL FIELDS OF THE CONTERMINOUS UNITED STATES

enrichment of the resultant molecules with hydrogen. It may be accomplished either underground (in situ) or by mining coal and transferring it to surface conversion plants. And it may produce either a liquid (liquefaction), a gas (gasification), or a combination of the two products in addition to by-products.

Although coal gasification and liquefaction represent a relatively simple concept, development and commercialization of an economically viable industry will require overcoming significant technical and environmental obstacles. One of the outstanding features of any future commercial coal gasification and liquefaction facility will be its size. A 250 million standard cubic feet of gas per day gasification plant or a 50,000 barrels a day liquefaction plant will process 15,000 to 25,000 tons of coal per day, often at high temperatures and pressures (greater than 1000°F and 3500 psi). Such a facility may require opening a large new surface mine or two large underground mines. It will require the containment and control of highly corrosive and potentially harmful process materials in large reaction vessels, perhaps exceeding 200 feet in height and weighing more than 1,500 tons. Including coal storage piles and water treatment ponds, the conversion facility may require more than a square mile of land and may employ about 4,000 people. The plant, mine, and associated new dwellings may affect up to 200 square miles of area. Additional areas may be affected by new roads, power lines, and pipe lines.

The total cost of such a facility can exceed $1 billion with an equivalent energy production of about 0.4 percent of current natural gas production.

The national benefits of coal gasification and liquefaction plants can be many and important. The plants can provide a critically needed supplement to our dwindling oil and gas reserves. The synthetic oil and gas produced may be environmentally compatible and clean burning. The products will be both storable and transportable, and synthetic oil and gas will make us less dependent on unstable and costly foreign suppliers, thus improving our balance of payments and increasing national security. However, to secure these long-term benefits, great care must be taken to avoid potential negative impacts on natural resources, the environment, and society.

Coal Gasification

Gasification of coal transforms coal into a convenient, clean, gaseous fuel or into synthesis gas (a mixture of carbon monoxide and hydrogen). Gasification processes may be classified into three categories, depending upon the heating values of the product gases:

1. Low-Btu gas options, 100-200 Btu's per standard cubic foot (scf), which use an air-steam mixture to gasify the coal, are suitable for use as an energy source near the point of generation, but because of their low-Btu content, are not economically attractive for long-distance transmission.

2. Medium-Btu gas or synthesis gas (500 Btu's/scf) options which use an oxygen-steam mixture to gasify the coal, can be used either as an energy source or as a synthesis gas for the production of chemicals and synthetic-liquid and gaseous fuels.

3. Synthetic pipeline gas (1,000 Btu/scf), indistinguishable from natural gas, is produced by further processing of intermediate-Btu gas. The required processing includes removal of particulate matter and condensables, and adjustment of the gas composition to a 3 to 1 mixture of H_2 to CO before methanation of the resulting gas mixture.

In Situ Coal Gasification

More than 85 percent of our nation's vast coal resource is not economically recoverable by conventional underground or strip mining. Underground coal conversion (UCG) processes could recover an estimated 1,795 billion tons of this unminable coal by converting it in place to clean-burning gaseous and liquid fuels. The goal of in situ (underground) gasification of coal is to convert coal without mining into combustible gases which are harvested by initiating combustion of a coal seam and injecting a current of air and oxygen or oxygen and steam. In situ combustion results in the production of an artificial gas rich in carbon monoxide, carbon dioxide, hydrogen, hydrocarbon gases, and other gases, depending on the substances injected and the method of combustion.

One future coal-based energy scenario estimates that in situ plants could comprise about 15 percent of the total coal usage by the year 2000 and 35 percent by 2050. The primary reason for this optimistic appraisal of in situ's potential is that compared to conventional mining of coal combined with surface gasification, in situ offers a number of significant potential advantages: tripling recoverable coal reserves, minimizing health and safety problems associated in the conventional coal extraction, reducing surface disruption and solid waste disposal problems, reducing water consumption, and reducing socioeconomic impacts. However, in situ gasification is not as technologically advanced as surface gasification. As a result, little research has been carried out on the potential health and environmental effects identified with this process such as degradation of the quality of groundwater, subsidence, and degradation of air quality from emissions through cracks and fissures.

The demand for products of in situ gasification falls into three areas as a function of gasification and upgrading options:

1. Low-Btu gas (produced by injecting air to the UCG reactor) for electric power generation and industrial fuels, at or very near the coal deposits
2. Medium-Btu gas (produced by injecting oxygen) for chemical feedstocks (e.g., ammonia and methanol production) for manufacturing facilities either onsite or a short pipeline distance away
3. High-Btu (produced by injecting oxygen and then upgrading the raw product in surface facilities) for injection into pipelines serving residential, commerical, and industrial customers

Coal Liquefaction

Coal liquefaction is the conversion of coal into liquids and by-product gases through the addition of hydrogen. There are several reasons for liquifying coal: Liquid fuels are more versatile than solid fuels and are generally easier to store, transport, and use; liquefaction facilitates removal of environmentally objectionable contaminates, e.g., sulfur, nitrogen, trace elements and ash; and liquefaction provides a means of substituting an abundant indigenous resource for imported petroleum.

It is anticipated that the major use of coal liquids will be for fuel, including a clean boiler fuel for electric generating plants and a synthetic fuel oil to produce gasoline, diesel fuel, and turbine fuels. Coal liquids may also be used as petrochemical feedstocks.

A wide range of process configurations and conditions exist within liquefaction technology. Currently, some twenty-odd processes are in various stages of development by industry and Federal agencies.

There are four major categories of coal liquefaction processes:

1. Direct Hydrogenation--processes in which coal is catalytically hydrogenated under high pressure and temperature, including H-Coal and Synthoil

2. Solvent Extraction--technology in which a solvent is used as a hydrogen donor to promote liquefaction, again under high temperature and pressure, including such candidate processes as Solvent-Refined Coal, Exxon Donor Solvent, and Co-Steam

3. Pyrolysis--thermal decompositon of organic components in coal in the absence of oxygen to produce solids (char), liquids and gases, including the char-oil-energy-development system (COED), clean coke system, Garret system, Coalcon, and Toscoal

4. Indirect Liquefaction--gasification of coal with steam and oxygen to produce synthesis gas (carbon monoxide and hydrogen) which is catalytically converted to liquid products, including the Fischer-Tropsch System and the Methanol System

The National Academy of Science* assessed coal liquefaction technology and concluded that of the four categories of coal liquefaction:

1. The most promising solvent extraction process (Exxon Donor Solvent) and the most promising direct hydrogenation process (H-Coal) should be carried forward to the demonstration phase.

2. Pyrolysis processes and indirect liquefaction processes do not appear promising for meeting the large fuel requirements of the United States.

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*Ad Hoc Panel on Liquefaction of Coal of the Committee on Processing and Utilization of Fossil Fuels, Assessment of Technology for the Liquefaction of Coal: Summary, National Academy of Sciences, Washington, D.C., December 1977.

RESEARCH HIGHLIGHTS

This summary is a brief condensation of the major problems identified in the six panel reports. The panel reports describe numerous problems and research tasks:

Panel Report	Number of Problems	Number of Research Tasks
Health Effects	10	54
Air Quality	7	26
Water Quantity, Quality and Aquatic Ecology	15	49
Terrestrial Effects	10	57
Ambient Measurment and Monitoring	22	39
Source Characterization	17	82
Total	81	307

In addition to problems and research tasks, descriptions of health and environmental effects and information needs are presented. This summary focuses on the highlights of the panel reports pertinent to the oil shale industry. The reader is referred to the individual panel reports for details regarding problem statements, data requirements, and specific research tasks.

Concerns

The panels concentrated their attention on the problems unique to coal liquefaction or gasification. In the case of aboveground technologies, the panels focused their attention primarily on the fuel system after the acquisition of coal.* Table I displays in matrix form the major health and environmental concerns in the coal gasification and liquefaction portion of the coal energy system (cells with dots indicate areas of concern).

Since most of the proposed gasification and liquefaction procedures have never been used commercially in this country, there is little information on occupational health hazards specific to these technologies. However, data derived from the handling and treating of coal in conventional technologies have provided information regarding potential hazards to both occupational and public health and safety. In addition, there are similarities in the problems associated with the utilization of coal gasification and liquefaction products and those associated with conventionally processed gases and liquid fuels, for example, the leakage of poisonous gases, exposure to pollutants, and the potential for fire, explosion, accidents, and equipment failure.

Although there are some differences in the pollutants generated by the use of synfuels as compared with those of conventional fuels, it is in the conversion phase of the process that the greatest concern exists regarding hazards to human health and the environment. Such concern focuses primarily on hazards associated with impaired air and water quality. It is in this phase, also, that the greatest gaps exist.

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*In another exercise, the Interagency Committee is devoting attention to the problems and research needs related to the extraction and physical cleaning of coal.

TABLE I

MAJOR HEALTH AND ENVIRONMENTAL CONCERNS IN THE COAL CONVERSION ENERGY CYCLE

	DELIVERY/ STORAGE	PREPARATION		CONVERSION			UTILIZATION		
	Storage and Handling	Crushing, Grinding, Briquetting, Etc.	Storage and Handling	Processing	In Situ Processing	Waste Disposal	Storage	Distribution	Consumption
PHYSICAL									
Air Quality	●	●	●	●	●	●	●	●	●
Water Quality	●	●	●	●	●	●	●	●	●
Water Supply	●	●	●	●	●	●	●		
Land Disturbance	●	●	●	●	●	●	●	●	
Subsidence					●				
Noise	●	●	●	●	●	●			
BIOLOGICAL									
Aquatic	●	●	●	●	●	●	●	●	●
Terrestrial	●	●	●	●	●	●	●	●	●
SOCIETAL									
Occupational Health and Safety	●	●	●	●	●	●	●	●	●
Public Health and Safety				●	●	●	●	●	●

Several panels were particularly concerned with the hazards engendered by accidents, spills, or process failures while workers were handling wastes. The need for careful selection of contractors for the hauling and disposal of wastes was pointed out in order to provide maximal protection both to the occupational sector and the public. These wastes, sludge, slag, and ash, represent a potential long-term source of pollutants that may be transported to ground or surface waters and could adversely affect aquatic biota and contaminate drinking water supplies. Contaminated water used for the irrigation of crops also may introduce toxic substances into food supplies. A concern, not measurable in chemical terms, is noise pollution which has a direct bearing on occupational health and safety.

An often voiced concern is the potential for land disturbance, particularly with regard to the potential use of vast areas of land for solid waste disposal. Land subsidence is of particular concern in the technology of in situ gasification.

Research Needs

The following summarizes the panels' specific problems and concerns and describes the research needs pertinent to the health and environmental effects of coal gasification and liquefaction technologies. The various panels focused on different aspects of the environmental and health effects of these technologies.

Panel Specific Concerns

The health effects panel assessed the effects of materials associated with coal gasification and liquefaction technologies in terms of their potential health hazards. The panelists voted that the following areas receive primary attention:

1. Analysis of potential releases of carcinogenic substances and quantification of risks to determine required controls and engineering design so that these technologies will be acceptable in terms of their effects on health
2. Identification of health problems for occupational epidemiology and surveillance, and monitoring and evaluation of occupational effects of exposure levels
3. Analysis of systemic, dermal, pulmonary, and genetic effects from toxic substances
4. Undertaking general planning, basic research, and occupational safety analysis

The terrestrial effects panel identified the following research needs in this area:

1. Review of the state-of-the-art of ecological baseline study methodology and data evaluations strategies
2. Identification of toxic forms of chemicals associated with these technologies and development of techniques for product and process waste materials
3. Development of basic research both in laboratories and at field disposal sites on factors affecting transport and transformation of wastes
4. Development of information on effluents and their effects and evaluations of statistical properties of pollutant exposures
5. Development of mathematical models for terrestrial ecosystems to better understand and predict environmental impacts

The source characterization panel concluded that research on source characterization should focus on the following areas:

1. Development and validation of tools, procedures, and equipment for sampling gas, liquid and solid streams, and fugitive emissions

2. Development of reliable and accurate procedures for characterization of organics in liquids and solids and analysis of hydrocarbon samples
3. Acquisition of defined samples in sufficient quantity and implementations of bioassay chemistry for the identification of unknown and known biologically active constituents
4. Development of scalable treatability and performance data on raw gas, liquid, and solid waste treatment systems

The air quality panel identified the following problem areas to be of prime importance. The areas are:

1. Anticipation of losses of volatile organic substances which are toxic or photochemically reactive in the plant vicinity and downhill
2. Effects of carbonyl sulfide on occupational or long-term, low-level exposure and techniques and acquisitions of data on these effects
3. Potential degradation of regional visibility, acid rain and health effects from increased atmospheric loading of primary particulate matter.

The Water Quantity, Quality, and Ecological Effects Panels focused on the problem areas related to both quantity and quality of water and the changes in the physical and chemical characteristics of the aquatic environment.

1. The availability and quantity of existing surface and ground water for development of coal gasification and liquefaction facilities
2. Development of stream flow requirements for protection of aquatic biota and maintenance of downstream water quality
3. The legal and institutional constraints on water use and water rights
4. The management and evaluation of water quality degradation related to leaching of contaminants from landfill disposal areas; aqueous discharge of inorganics, organics, and trace elements; emissions from combustion products; and airborne release of contaminants

5. The design and implementation of environmental research on chemical characterization of toxicological screening of coal gasification and liquefaction contaminants as predictions of their ecological effects

Finally, the ambient measuring and monitoring panel identified the following areas:

1. Development of occupational surveillance measurements and monitoring strategies for pollutants of upcoming commercial plants

2. Design and conduct pollutant baseline, characterization, and monitoring studies to encompass pollutants of most concern to the protection of human health and the environment

3. Conduct ambient characterization studies encompassing highly defined set of chemical species to determine ambient levels associated with the plant

4. Development of reliable analytical techniques for measuring nonchromatographable organic compounds and organic constituents of airborne particulate matter as well as heterocyclic compounds carbonyl sulfide, and hydrogen cyanide

5. Development of comprehensive interlaboratory quality assurance programs to develop standard reference calibration materials suited to ambient measurement methods

6. Determination of leachable substances from wastes and their long-term monitoring, and measurement of long-term ground water pollution from in situ processes as well as of ambient products of end-use combustion of coal.

It should be noted that several panels often converge on the same research needs. These needs are grouped into eleven major research areas and are discussed in the following sections.

Major Research Areas

Source Emission Data

One of the common information needs identified was for source emissions data from all phases of coal gasification and liquefaction.

Review of the process steps in aboveground coal liquefaction and gasification indicated that there were strong similarities in the types of chemical compounds present. Thus, the pollutants were generally considered by the panels without separate reference to liquefaction or gasification in defining air quality problem areas. Air Quality problems associated with in situ processes were regarded as occurring principally in the later stages (i.e., utilization), and would, therefore, involve the same types of pollutant emissions as other coal gasification and liquefaction technologies.

The air quality panel specifically cited the need to identify emissions data from existing conversion units. It also recommended that emissions from existing oil refineries be monitored, while noting that coal gasification and liquefaction facilities are likely to produce greater percentages of aromatic hydrocarbons than would a conventional oil refinery.

Another need noted is data on baseline air quality of an area before a coal gasification or liquefaction unit is established. This is necessary in order to determine the synergistic effects resulting from the interaction of emissions of the unit with pollutants already in the area.

The major emissions identified result from: (1) the pretreatment stage (e.g., organic tars), (2) the coal gasification and liquefaction facilities (e.g., toxic chemicals from aqueous condensates in cooling towers, emissions of sulfur and nitrogen oxides, and particles from steam boilers), and (3) leaks and equipment failures (planned venting, pressure letdown, and fugitive emissions may have a severe impact on air quality).

Another need with regard to air emissions, specifically identified by the air quality panel, is the establishment of reliable air quality simulation models over a wide range of distances for plants in two types of areas: (1) complex terrain and (2) industrial-urban complexes.

Solid Waste

All proposed coal gasification and liquefaction technologies will produce large masses of solid materials to be disposed of or left (e.g., from in situ gasification) under the soil surface. The greatest volume of pollutants to the environment will result from disposal of solid wastes. These solid wastes include raw materials, process additives, residuals from sulfur control, incompletely processed product, and even abandoned equipment.

The large areas of land that would be involved, either at the mines or at alternative dumpsites, are regarded as only one phase of the problem. Additionally, the release of pollutants from discarded wastes can migrate through the water table or can be released through transpiration or wind erosion to contaminate surface vegetation and drinking water supplies. The transport, fate, and effects of these materials, both physical-chemical and biological, as modified by local environment factors such as climate, topography, soil structure/chemistry and groundwater hydrology, need to be determined.

Since little is known regarding the effects of this disposal, the impacts associated with solid wastes and their leachates were given high priority by the terrestrial and water quality panels. Included in the information needs associated with solid wastes and their emissions and effluents are: (1) thorough physical and chemical characterization, (2) identification of potential pollutants. (3) acute (immediate) effects, and (4) chronic (long-term) effects, particularly food chain effects.

Included under solid wastes are two types of wastes that may result from coal gasification and liquefaction processes:

1. Residual wastes, which are produced regularly with a high degree o[illegible]istency in physical-chemical makeup, such as ash/slag, [illegible]bber sludge, etc.
2. Process wastes, which are highly variable and infrequent in production

The latter type of wastes, which are typically part of a processing step and are not commonly handled, may result from a valve, pump, or line failure. These process streams may be under high pressure or high temperature and pose a serious danger to occupational safety.

The several methods of disposal may involve threats to both air and water quality:

1. Incineration--a process that, while producing a less voluminous ash product, may cause more air pollution and produce a more concentrated toxic product
2. Direct land disposal--a process that requires handling of larger volume of wastes and presents a greater potential for toxic materials to enter the aquatic environment

The segregation of wastes for selective incineration and land disposal, as well as the reuse of solid wastes may minimize air and water impacts.

Gas Emissions

The primary concern relative to gaseous air emissions is their incremental effect on existing and possibly substantial background levels. In local areas, these may increase the number and magnitude of chronic ecological effects attributable to sulfur and nitrogen oxides and oxidant and particulate complexes acting through both wet and dry deposition. However, while considerable work has dealt with acute exposures of some pollutants and pollutant combinations to crops, little has been done to identify chronic effects.

Another problem relates to coal gasification facilities, which may emit substantial quantities of gaseous substances such as carbonyl sulfide. Few investigations have been conducted in this area, and information is needed regarding both acute and chronic exposure to both vegetation and animals.

Transport, Transformation, and Fate

Transport, transformation, and fate phenomena cut across several areas of environmental concern, i.e., air quality, water quality, and aquatic and terrestial biota.

Numerous studies have been performed, and substantial resources allocated to investigating these phenomena in existing energy sources. However, while there are similarities between the emissions from existing coal-fired power plants, coking ovens, and petroleum refineries and the emissions associated with coal gasification and liquefaction facilities, most research efforts have been directed at large utility facilities rather than the smaller steam boilers which will be operated in conjunction with coal gasification and liquefaction facilities.

The potential transport of contaminants into surface waters from the combustion of synthetic liquid fuels was considered a major problem by the aquatic panel because the types and levels of trace organic contaminants produced are likely to differ from those derived from either the direct combustion of coal or of fuel oil. In addition, once contaminants have entered surface or groundwater, they will be subjected to a variety of transport and transformation processes. Transformation processes will be affected by the classes of contaminants released, their concentrations, and the characteristics of the receiving water (e.g., pH, temperature, salinity, flow rate). For example, salts and trace metals may precipitate or adsorb onto suspended or sedimented particles, whereas trace organics may be altered by photolytic, or microbial degradation.

Furthermore, the aquatic panel emphasized that the processes which transport, transform, concentrate, or remove contaminants form a critical link between what is actually released in the discharge and the potential for adverse effects on aquatic organisms or humans. If transport rates of toxic contaminants are low or if rapid degradation to nontoxic forms occurs, potential health and ecological impacts will be redirected to small areas near the source. Conversely, if transport rates of toxic substances are high or degradation occurs slowly, potential health and ecological impacts may occur over large areas.

Water Use

Insufficiency of data available to justify the separation of the development and implementation of coal gasification and liquefaction technologies and their impact on the aquatic environment resulted in the joint consideration of these technologies by the aquatic panel. Some of the major concerns of the panel included the availability of water, its transport, the fate of inorganic and organic substances produced or mobilized by the conversion process or effluent disposal, and the potential ecological effects resulting from chronic low-level exposure to effluent components.

Aquatic problems resulting from in situ gasification were regarded as similar to those identified with in situ oil shale development, namely groundwater contamination from combustion zones and surface subsidence. Groundwater contamination may result from mobilization and leaching of trace elements, inorganic salts, and organics (e.g., phenols, aromatic hydrocarbons) from the combustion zone. Subsidence may disrupt flow patterns of underground aquifers, having major effects upon future water availability.

The availability of water is regarded as a prime consideration in regional energy planning, the siting of facilities, and the design of process options for both coal liquefaction and coal gasification technologies. The water requirements for these technologies depend on the type of coal utilized, the process options employed, the cooling systems and water recycling technologies used, the requirements of the labor force and induced development, and the environmental characteristics at the site of development. These factors need to be integrated so that process options and water conservation strategies can be optimally selected for specific regions of commercial development. To evaluate the impacts of coal gasification and liquefaction technology development, analyses of local and regional water supply and demand and water management techniques are needed.

Potential direct aquatic problems associated with the operation of aboveground coal gasification and liquefaction processes arise from atmospheric and aqueous effluent releases, from residue disposal requiring land utilization, from product and process spills, and from consumptive water use by a facility.

Atmospheric releases were considered lowest in priority with respect to direct aquatic effects, although indirect effects such as acid precipitation may have substantial implications for water resources and aquatic productivity. Much more information on the composition, transport, and deposition of atmospheric releases is necessary before an adequate assessment of the role of coal gasification and liquefaction in acid precipitation can be made.

Direct stack emissions from synfuel processes pose little hazard for aquatic environments, although cooling tower drift and deposition may give rise to both terrestrial and aquatic problems. Cycling of contaminated process water through cooling towers, coupled with the practice of chlorination, suggests the potential for the creation and release of organic and chlorinated organic compounds about which little is known.

Effects of Complex Mixtures

Several of the panels identified effects of complex mixtures of pollutants as an information need. In those cases where studies have been conducted regarding the effects of complex mixtures of pollutants, indications are that such effects may be greater than would be expected from the sum of the effects of the individual pollutants. Thus, such possible synergistic effects need to be identified.

Land Use

Implicitly or explicitly, land use, particularly for disposal of solid wastes and their potential leachates resulting from coal gasification and liquefaction technologies, was identified as a primary concern for all panels, since such land use affects air, water, and terrestrial concerns and thus individual and public health and welfare.

All types of coal gasification and liquefaction facilities will require the commitment of large land areas for both the conversion plant and for supporting operations. Such dedicated land use will require information regarding siting criteria, total land requirements, compatibility with existing land use, water demands in relation to availability, water quality, and effects on other ecological considerations (e.g., air quality, wildlife). In addition, reclamation strategies for land disposal sites need to be identified.

Baseline Information

Baseline information needs are identified in all of the panel reports. In order to evaluate impacts of coal gasification and liquefaction techniques, baseline conditions in the air, water, and terrestrial areas must be identified. Such baseline information is particularly important because of the relative newness and uniqueness of coal gasification and liquefaction technologies. The Terrestrial panel especially recommended that because year-to-year variation may be extreme, not only is there need for a baseline mean, but also for a baseline variance to be established for each biological parameter to be measured. The Ambient Measurement and Monitoring panel specifically recommended that during initial plant operations, baseline studies should be expanded to encompass a more highly defined set of chemical species in order to determine ambient levels associated with the plant.

Monitoring and Sampling Methods

While all of the panels called for vigorous measurement and monitoring programs, specific needs associated with this area are identified in the Ambient Measurement and Monitoring panel report. It calls for more intensive occupational environmental pollutant measurement programs than are currently planned. The panel felt that the measurement of unregulated environmental pollutants has been most neglected.

In order to protect current workers and to define monitoring strategies for pollutants in future commercial-scale synfuel plants, the identity and concentrations of pollutants to which workers are exposed in demonstration plants is needed. Ongoing surveillance measurements of hazardous emissions are required. Monitoring throughout a plant's lifetime of a selected set of pollutants is necessary to detect unforeseen trends which may develop.

In the area of sampling, research needs centered on the preservation and extraction of organics from ambient samples (air and water). The need to establish the validity of groundwater samples collected in the assessment of in situ coal gasification is of high importance.

Special measurement studies are needed. These are the determination of leachable substances from synfuel waste and their long-term monitoring, the long-term measurement of groundwater pollution from the in situ process, and ambient measurements of end-use combustion of synfuels such as in vehicles, ships, or power plants not colocated with a conversion facility.

Quality Assurance

All of the panels noted the importance of quality control and quality assurance of all data in order that valid interpretations and conclusions may be reached. Particularly, the Ambient Measurement and Monitoring panel identified the need for a comprehensive interlaboratory quality assurance program for all labs participating in the recommended monitoring programs. Included within this program is the need to develop standard reference calibration materials suited to ambient measurement methods. Recommendations in this regard include appropriate sampling techniques, adequate scaling, establishment of criteria and guidelines for data collection, and interdisciplinary exchange of information.

Epidemiological Surveillance and Toxicological Testing

Several panel reports cite needs related to epidemiological surveillance, particularly with regard to occupational exposures. The Ambient Measurement and Monitoring panel placed high priority on access to epidemiological information on the toxicological, especially carcinogenic aspects of coal tars, both through available retrospective data from non U.S. sources and through the development of instrumentation for measuring real-time exposure rates of workers. The Terrestrial Effects panel identified a need for toxicological screening, the determination of exposure levels to pollutants for occupational personnel, and the determination of toxicity levels.

The Health Effects panel placed primary emphasis on an understanding of the carcinogenic process through epidemiological research and utilization of the derived knowledge in the selection among competing gasification and liquefaction processes in an attempt to minimize carcinogenic and other health risks. A second benefit to the results of such research would be the guidance it would provide for engineering design to assure adequacy of protection from process effluents, wastes, and products. In addition to carcinogenesis, the Health Effects panel cited information needs related to such other areas as dermal, pulmonary, genetic, reproductive, behavioral, and system effects.

PANEL REPORTS

The panel reports presented in this section are a product of the participants at the workshop. These reports have been retained in their distinctive, original style as prepared by the panel chairmen or designated authors. The report of each panel (except for Ambient Measurement and Monitoring which was compiled from workshop working papers), was reviewed by the panel participants and revised according to their comments.

HEALTH EFFECTS

1.0 INTRODUCTION

While oil and natural gas production in the U.S. is declining, there are still vast coal reserves. If coal could be converted to usable substitutes for these fuels at reasonable economic and environmental cost, domestic oil and natural gas reserves would be extended and dependence on petroleum imports lessened. This would also increase the available lead time for development of non-depletable energy sources. Gasification is an old technology that has fallen into disuse in this country. Product gases can be used as produced, upgraded to natural gas equivalents or converted to liquid fuels. Coal can also be directly hydrogenated and pyrolyzed into liquid fuels. Since most of the proposed gasification and liquefaction procedures have never been used commercially in this country, there is little information on general occupational health hazards.

All conversion technologies involve processing of coal similar to that which is done prior to direct combustion. Consequently, the potential hazards of processing, such as dust inhalation leading to pneumoconioses, are well established. Conversion involves heating coal under high pressure and temperatures. The hazards here may include possible leakage of poisonous gases some of which are process-specific, exposure to criteria pollutants, and the possibility of fire and explosion.

This conference had as its objective the identification of those problems unique to coal conversion, placing a decreased

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emphasis on generic fossil fuel issues which will be the subject of future study. Potential biological effects and safety hazards are identified for both the general and occupational populations, but emphasis was placed on detection of possible occupational effects since workers are generally exposed to larger pollutant doses and are more likely to develop adverse health consequences before they are detectable in the general population.

1.1 Approach

The panel first met as a whole and each member described his particular expertise and current research areas. The entire panel then proceeded to discuss the potential health hazards associated with the more prominent coal liquefaction and gasification sub-technologies. Each stage in the fuel cycle was considered from mining to solid waste disposal and combustion of the coal conversion products.

The panel proceeded to identify a number of general areas in which they felt additional research was required to assure that the health and safety effects associated with the development of coal conversion technology would be understood and controls could be applied if necessary. These are as follows:

- carcinogenesis
- genetic development and reproductive effects
- behavioral and neurotoxic effects
- systemic/skin effects
- pulmonary effects

- occupational epidemiology and surveillance
- monitoring - occupational exposure
- effects of fires associated with gasification/liquefaction products
- catastrophic accidents
- basic research

From among the panel members, based on their areas of expertise, subpanels were designated to address each of the identified problem areas. The groups were asked to prepare problem statements and to identify supporting research needs. In addition, each group was asked to assemble introductory material summarizing the problem statements and discussing them in relation to the whole technology development process. This material has been incorporated into this report wherever possible.

Representation on the Panel

A wide range of backgrounds, organizational affiliations and professional disciplines was represented on the panel. A listing of panel members is contained in Appendix A.

2.0 SPECIFIC PROBLEM STATEMENTS AND RELATED RESEARCH REQUIREMENTS

The concerns of the health effects panel can be divided into four main areas:

1. Toxicological effects
2. Epidemiology and surveillance
3. Safety issues associated with major process accidents and catastrophes, and
4. Basic research needs

The first three areas are broad and include a number of individual problem statements which address more specific issues. In the following text, the individual problem areas are identified within each main area and are presented along with the related information needs and the research required to address the problems.

2.1 Toxicological Effects

Workers engaged in the conversion of coal to liquid and gas products and those engaged in the delivery of these products to their ultimate destination may be exposed chronically via skin, inhalation and ingestion to unknown levels of potentially toxic but as yet biologically uncharacterized liquid, gaseous and particulate emissions, and/or solid waste products. Massive acute exposure to these same potentially toxic materials will also be possible during maintenance and repair operations or as the result of accidents.

Human exposure to the products and degradation products of coal conversion will also be possible as a result of end use. Here the workers engaged in the commercial utilization of these products will be at risk as well as the general population, i.e., homeowners and their families and service personnel when these products are used as fuel in power and home heating plants. These groups may be exposed chronically to small concentrations via skin and inhalation and acutely to large amounts during maintenance and repair operations or as the result of accidents. Any risk may be enhanced when the new products are used to heat private homes because of an expected lower level of precautions and a lack of technical knowledge of furnace operation.

In both the acute and chronic exposure situations, the nature of the response reaction is primarily dependent on the route of exposure, the dose received, and the potential for biological activity of the pollutant.

Before a health effects research program can be initiated, much information is required on the identity, amounts and biological activity of the various pollutant species associated with the various gasification and liquefaction options. Minimally, researchers should soon be able to obtain samples from the SRC I and II, H-Coal and Exxon Donor Solvent coal liquefaction processes and the Koppers-Totzek, Lurgi, Wellman-Galusha and Wiskler processes for coal gasification which are thought to be most likely to be commercialized in the near future. The nature of the pollutants is a function of the coal resource, the coal conversion technology and the manner of use. Such factors must be considered in estimating the exposure hazard.

Following pollutant exposure, a number of adverse reactions are possible including carcinogenesis, localized skin effects, pulmonary effects, genetic reproductive and developmental effects, behavioral/neurotoxic effects and other target organ systemic effects. Each such category of effects will be addressed in greater detail.

2.1.1. Carcinogenesis

Carcinogenesis is probably the dominant health concern with regard to the coal conversion industry. The conversion processes involve reaction of coal at high temperatures and pressures where many polynuclear aromatic hydrocarbons can form, e.g., benzo(a)pyrene, dibenz(a,h)anthracene, chrysene, and 7-methylbenz(c)acridine, as well as aromatic amines, e.g., -naphthylamine and benzidine. In addition, benzene, a leukemogenic agent for man, is present in coal tar, as are several trace metals such as chromium and arsenic which can be carcinogenic. Therefore, though the exact mixture of potential carcinogens present will vary depending on the process and the coal feedstock, in the developmental stages the industry is approaching coal conversion processes as if carcinogens were present in each type of process.

In recent years there has been a strong interest in the identification and elimination of environmental pollutants as causative agents in human cancer. The epidemiological evidence based on geographic differences in cancer experience in indigenous populations and migrants indicates that 80 to 90 percent of human cancer is due to environmental agents. Similarly, there has been an increase in the number of Federal regulatory efforts to reduce cancer occurrence by banning carcinogens or by minimizing exposure to them.

The dominant concept in the regulatory arena at the present time is based on the linear non-threshold dose-response relationship for cancer development. Such a relationship means that any exposure, however small, will cause an excess risk of cancer, the magnitude of which is proportional to the dose. Here, even very low levels of exposure may give calculable excess numbers of cancer deaths when large populations are exposed. This nonthreshold dose response model is only one of several being considered by the scientific community at the present time.

The number of workers exposed to recognized and suspected carcinogens in the coal conversion industry is relatively small, however, exposure may be very high. There is a potentially larger general population surrounding the conversion facilities which, on the other hand, would be exposed to much lower levels of carcinogens. All possible routes of exposure need to be considered.

In one study of 359 workers at a small Union Carbide coal liquefaction (hydrogenation) pilot facility at Institute, West Virginia, which operated for 10 years from 1952 to 1962, an increase of 20 times the expected number of skin cancers was noted among the workers based on incidence rates in the general U.S. population.[1] National

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[1] Sexton, R. J., C. S. Weil and N. I. Condra, Arch. Environ. Health 1:181-231.

Institute of Occupational Health and Safety (NIOSH) conducted a follow-up mortality study on the 50 workers with diagnosed skin cancer and precancerous conditions. They concluded that the rate of skin cancer development was decreasing and that none of the skin cancer victims had developed subsequent systemic cancer.[2] It is important to note that 6 of 10 of the skin cancer cases occurred in maintenance workers.[3] The fact that this was a small scale study must be kept in mind and the statistics might not be generalizable to larger populations. The observed effects in this case study seem to have been limited to skin cancer. The willingness of Union Carbide to publish these findings has resulted in many changes being made in their facilities and operating procedures and in similar changes in other facilities to reduce human exposure.

In 1977 NIOSH conducted a preliminary survey of coal gasification facilities in East Germany, Scotland and South Africa. The two European facilities were only being operated on an experimental low production basis. The Lurgi gasification facility at Sasol, South Africa, is, however, in full scale commercial operation and has been since 1952 and expansions are planned to Sasol 2 and 3. Medical records are available on both black and white employees which date back at least 20 years though their completeness is unknown. There is an 11 percent turnover rate overall with a higher rate for whites blacks. Many of the blacks work on an annual contract renewal basis and at the time of each renewal they receive a chest X-ray and a minimal physical. In general, the blacks perform the more menial tasks. The major cause of death in Sasol is coronary heart disease which may be aggregated by high levels of alcohol and tobacco consumption. The role of occupational exposure has not been studied.

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[2] National Institute for Occupational Safety and Health: Quick Response Evaluation of Energy Related Occupational Safety and Health Programs. Task Order 1: Mortality Study of 50 Workers Exposed to Coal Liquefaction Processes at a Union Carbide Plant, Menlo Park, CA, Stanford Research Institute, 1977.

[3] National Institute for Occupational Safety and Health, Occupational Exposures in Coal Gasification Plants, September 1978.

In conjunction with the NIOSH survey a number of employees were interviewed and evidence was sought for skin cancer or chronic lung disease. Occasional skin problems were found including some urticaria and a few cases of skin cancer (among whites) but no traces of systemic cancer or any detectable causality. The Sasol facility has employed modern control technology, though the past less stringent control areas might also have influenced the health of the occupational population. This Sasol facility represents a rare opportunity to undertake a full epidemiology study with 20 years of data readily available and a high degree of cooperation from facility management.[4]

It remains to be seen therefore whether the projected philosophy that coal liquefaction products contain far higher levels of carcinogens than the comparable petroleum products will result in excess systemic cancer cases, especially among the occupational population.

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[4] Ralph Yodaiken, NIOSH, personal communication, March 1979.

Where regulatory controls for carcinogens concerning both occupational and general population exposure have been applied, and where there has not been an outright ban, the level of control has been severe in relation to the controls commonly applied to noncarcinogenic toxicants. Generally carcinogens are controlled to a level which represents a lifetime risk of less than 10^{-4} -10^{-5} using the linear non-threshold extrapolation model. There is every reason to believe that similarly strict controls will be applied to the coal conversion industry including exposure of workers and the general population to process effluents and products. It is quite possible that the strictness of controls required for carcinogens will simultaneously reduce the hazards from non-carcinogenic toxicants to negligible levels.

At this stage in the development of a new U.S. coal conversion industry, an associated research program should have three main objectives concerning the possible associated carcinogenic risk. First, the research program should assist in the selection among competing gasification and liquefaction processes and product uses as an attempt to minimize carcinogenic and other health risks. Second, potential sources of carcinogen exposure to workers and the general population should be identified to provide guidance to engineering design to assure adequacy of protection from process effluents, wastes and products. Third, the research program should improve our basic understanding of the carcinogenic process as it relates to

(a) dose response relationships of carcinogens, incomplete carcinogens, cocarcinogens, promotors, anticarcinogens, (b) the structure-activity relationships and mechanisms of the above, (c) the factors that determine differences in species susceptibility in order to improve the applicability of animal tests to man, (d) the improvement of short-term tests for carcinogenicity, and (e) the basis for differences in susceptibility of humans to carcinogens including techniques to identify and protect susceptible individuals.

It is only through a broad research program to improve our basic understanding of carcinogenesis that the control of carcinogens in the work place and the general environment will be put on a more rational basis.

2.1.1.1 Characterization of Potential Carcinogenic Hazards. In order to more adequately quantify the risks to the occupational and general populations exposed to coal conversion effluents, wastes and products, these materials and various fractions thereof must be tested for the presence of carcinogens, incomplete carcinogens, cocarcinogens, promoters and anti-carcinogens. Special attention should be given to the possible pollutants from the H-coal, SRC I and II and Exxon Donor Solvent coal liquefaction and Co-gas, Slagging Lurgi, Fixed-bed Lurgi and Hi-gas coal gasification processes since they are now considered most likely to reach commercialization in the foreseeable future.

Task 1 - Potency assays should be conducted on the products, emissions effluents and wastes (liquid, solid and gas) from the most promising coal conversion processes. These assays should be conducted first on whole streams then on various fractions. Only after these initial tests, should the carcinogenic potential of individual pollutants be determined. Existing data are very fragmentary and completely inadequate to assess the carcinogenic risks associated with the various coal conversion options.

Task 2 - The active pollutants should then be tested in parallel with benzo(a)pyrene, cigarette tar, aromatic amines, coke oven emissions and petroleum products. There is some question at the present time whether BaP can be used as an indicator of carcinogenic potential. This type of comparative analysis of several active fractions versus BaP content and determination of carcinogenic activity could provide the basis for resolving this issue. Cigarette tar should be included in the potency assays since it represents a potentially confounding variable. Since the carcinogenic products, emissions and effluents from coal conversion technologies have been compared to those from coke over emissions, the inclusion of coke oven species in the test would again serve to validate this comparison.

Task 3 - For the major technological gasification and liquefaction options a panel of experts should be assembled to estimate the potential for exposure to carcinogens and the risk of developing cancer for various segments of the exposed populations.

2.1.2 Dermal Effects

Exposure of the skin to liquid, gaseous and solid pollutants associated with the coal conversion processes represents a major occupational hazard to the workers in these facilities. In the studies on the Sasol plant in South Africa conducted by NIOSH, skin effects including both dermatitis and sensitization reactions represented the major worker complaint. Similarly in the coke ovens and petrochemical industries, skin effects are common complaints from pollutant exposure. For these reasons, the expected fugitive emissions, the liquid and gaseous effluents, the solid waste products and the intact, and if appropriate, fractionated end products from the principal liquefaction and gasification processes should be investigated.

Task 1 - The above materials should be tested for ability to induce contact dermatitis or sensitization in rabbits and mice using standard dermal toxicity testing procedures. These studies should include experiments to determine the possible effects of photochemical activation. Appropriate occular toxicity studies might also be considered.

Task 2 - The ability of the various process, product and waste stream fractions to penetrate the skin should be determined. Where individual fractions and species can be shown to be absorbed, the reaction should be quantified and the total dose absorbed should be determined as a function of the concentration and duration of exposure. To accomplish this, it may be necessary to develop new analytical and chemical detection methods. These data will be extremely useful for estimating the total dose received involving multiple routes of exposure. Mechanisms for removing skin contamination should also be studied.

2.1.3 Pulmonary Effects

The potential exists for airborne release of potentially toxic aerosols and vapors at various stages in both coal gasification and liquefaction fuel cycles. Workers may be exposed to significant concentrations of these airborne toxicants. The general public may also be exposed either because of environmental releases, or in the course of handling and/or combusting the product fuels.

Dust particles of coal, silica, ash, solid sludges and slags will be associated both with the pretreatment operations of crushing and grinding, and with storage and disposal of the solid wastes. These dust particles may contain trace metals such as antimony, arsenic, boron, cadmium, fluorine, lead, mercury and nickel. In addition various organics and inorganics may be adsorbed on the particle surface. Inhalation of dust particles in the 1 micron range is likely to result in their deep penetration and retention in the lung and hence possible introduction into the body. The disease of pneumoconiosis, or black lung, has been known for many years among coal miners exposed to coal dust. Exposure to coal preparation activities could result in similar disease development, though this problem has not been identified at existing foreign coal conversion sites.

In addition to the hazards from dust particle inhalation, workers are also exposed to fugitive emissions in the process plant, exhaust releases from combustion aerosols and vapors which negotiate exhaust system abatement equipment, evaporation of spilled liquids, aerosolized process liquids, aerosols and vapors released in handling wastes, and combustion products from the end use of the prepared fuels.

Many of these types of inhalation exposures are very similar to exposures occurring in other fuel cycles, such as exposure to coal dust, SO_x, NO_x, CO, CO_2, H_2S, COS, CS_2, HCN, and NH_3. Evaluation of pulmonary effects from such agents in most cases can be accomplished based upon existing knowledge. However, effects of combinations are not known and there are toxicants produced in coal conversion processes whose biological activity is not adequately understood. Such toxicants occur as complex mixtures, so that antagonisms and synergisms between constituents are possible. Thus, laboratory experiments will be required using appropriate experimental animal models and inhalation exposures to hazardous emissions and effluents. In these studies, care must be taken in selection of materials to assure that those materials used in exposure studies are representative and have a reasonable probability of release, since many toxic agents may not constitute a hazard because of existing control technology.

The effect of greatest concern from inhalation exposure is respiratory cancer, but fibrogenic disease, emphysema, and functional disorders must also be considered. The relative importance of cancer and direct injury to the lung will depend upon dose-response relationships that need to be elucidated for each candidate emission mixture. Smoking may again be a confounding factor.

Agents that could be selected for study from the following categories: (a) trace metals from emissions and flyash alone and in conjunction with vehicle aerosols, (b) organic compounds specifically representing complex mixtures of polycyclic hydrocarbons and heterocyclic species that may be released in various stages of the fuel cycle and may be absorbed on particulate matter, (c) specific species or agents identified to be of importance because of their formation in process streams such as COS, metal carbonyls ($Ni(CO)_4$, $Fe(CO)_5$), oil mists, and phenols, and (d) combinations of the above in mixtures that may be inhaled due to releases in various stages of the respective fuel cycles for gasification and liquefaction of coal. Obviously to investigate all of these would be prohibitively expensive so care must be taken to select those species most deserving of research.

In identifying the hazards associated with respiratory exposure to toxicants, both by adsorption through the lung and by pulmonary clearance and absorption through the GI tract, effects should be sought in organs other than the lung. The deposition, metabolic behavior, and excretion of inhaled toxicants must be studied in order to evaluate the probable target organs for effects from inhalation deposition of various constituents and the pathogenesis of resultant disease.

2.1.3.1 Effects of Inhalation of Coal and Other Dusts. Chronic exposure to respirable coal dust and other dusts containing crystalline free silica can produce lung diseases known as pneumoconioses. These can be disabling and progressive, leading to death even when exposures cease. Compensation payments to coal miners with diagnosed disability are currently approaching \$1 x 10^9/year. Since coal liquefaction and gasification represent new technologies, all possible steps should be taken to assure that inhalation hazards are minimized. It is important, however, to determine the extent to which the dusts from these processes represent hazards.

The coal handling and preparation steps at the beginning of all gasification and liquefaction processes are inherently dusty, and can readily lead to excessive occupational exposures unless effective dust suppression and/or exhaust controls are installed and maintained properly. Similarly, ash and/or slag from gasification operations will generally contain sufficient free silica to present a potential silicosis hazard, unless adequate dust controls are employed. Char and other carbon-rich solids from liquefaction and from some gasification operations may also produce excessive concentrations of airborne dusts. However, the hazards associated with these dusts are not adequately defined. They may be hazardous with respect to the initiation of one or more types of pneumoconiosis. They may also, in addition, result in cancers in the lungs, or even in other organs when they act as carriers for carcinogens. Partially oxidized hydrocarbons, of the types likely to be in chars, should be evaluated for potential carcinogenic activity.

Sufficient data are available on the hazard of coal dust and coal ash inhalation; no further research is needed although required medical surveillance may provide additional data. However, only minimal data exist on the hazard of inhaling dusts from the disposed chars from coal conversion facilities.

Task 1 - Data are needed on the carcinogenic and fibrogenic potentials of inhaled char solids, ash and slag dusts containing significant proportions of partially oxidized hydrocarbons. Among the data needed are:

1. Retention times within the lungs and lymph nodes
2. Clearance pathways and storage depots
3. Effects on cells at deposition sites and along clearance pathways
4. Metabolic transformations within the lungs and secondary depots
5. Identification of target organs and target organ effects
6. Mutagenic activities of particle extracts, with and without metabolic activation, and
7. Carcinogenic potency on mouse skin.

In order to obtain these data, inhalation studies of respirable chars should be conducted. Ideally the investigation should include intratracheal instillation, and sub-acute and chronic inhalation exposures.

2.1.3.2 Inhalation Hazards Associated with Process Upsets. During the operation of coal liquefaction or gasification facilities process upsets are likely to occur which could represent immediate hazards to health through direct injury or impairment in function of the respiratory system. Similarly, during maintenance and repair operations, the personnel involved are likely to be exposed to significantly greater quantities of residues and vapors which may be hazardous if inhaled.

Respiratory failure can result from excessive exposure to certain gases present at high concentrations in reaction vessels, which may escape from leaks or process upsets. Carbon monoxide represents a particularly dangerous potential for hazard in the coal conversion industry. Its dangerous properties are well-known and the TLV has been set at 50 ppm to reflect this. Similar processes in the chemical and petrochemical industries have been associated with fatalities and acute poisonings following exposures to carbon monoxide and hydrogen sulfide (TLV = 10 ppm). Maintenance work in enclosed vessels can also lead to excessive exposures to these gases if they are not adequately vented, or if the workers are not supplied with supplementary breathing air. The air in closed vessels can also be deficient in oxygen, or have an excessive concentration of nitrogen dioxide (TLV = 5 ppm). Other chemicals which may be present in some conversion operations, and which may cause fatalities, include hydrogen cyanide, carbon disulfide, and metal carbonyls.

Task 1 - The potential for exposure to toxic substances through inhalation should be determined for each facility by a competent industrial hygiene staff. Where the potential effect of various substances or process mixtures is unknown, animal research should be instigated to address the problem. Where potentially hazardous situations are identified, control technology or operating procedures should be initiated to protect the workers. In most cases this problem has been adequately studied and control technology is available.

2.1.4 Genetic, Reproduction and Developmental Effects

Genetic diseases and birth defects already place a heavy burden on society. It is obvious, therefore, that we must minimize the possibility of coal conversion technologies contributing to this burden. Therefore, the objective is to prevent or minimize human exposure to those various process components of coal conversion technologies which can be shown to be potential mutagens and/or teratogens.

Although it remains to be determined whether coal conversion activities present a high-risk problem for man, there may be some potential for genetic and teratogenic impacts. This raises the need for an intensive process-oriented testing program to adequately study process mixtures and individual fractions for mutagenicity and teratogenicity and thus identify the specific chemicals that have mutagenic and/or teratogenic properties. Information that will be obtained from these studies should be useful in risk estimation.

Similarly, many of the chemicals associated with coal conversion technologies have biological activity but have not been adequately studied for possible effects on the reproductive system. There have been reports indicating that a number of chemicals interfere with fertility in man. Thus, there is a need for adequate *in vivo* studies of the coal combustion process mixtures and specific chemicals for effects on reproductive performance.

2.1.4.1 *Materials from Coal Conversion May Represent a Mutagenic Hazard*. Because of the anticipated growth of the coal gasification and liquefaction industries, products, by products, effluents and emissions need to be evaluated to determine their mutagenic potential. In choosing compounds to be tested, emphasis should be placed on samples from process streams after control technology has been applied. Also, mixtures should be assayed first for mutagenic activity then the biologically active species identified and used in longer term testing. Several mutagens have already been identified for coal conversion processes including thioacetamide, acetanilide, A-hydroxylaniline, hydroxylamine and n-propylmethanesulfonate. The strength of their mutagenic activity should be determined and the process locations where their location in the process stream identified.

Task 1 - Classes of chemical agents which are likely to be found in coal conversion materials (e.g., metals, aromatic amines) have not been well characterized with respect to mutagenesis. Representative compounds should be subjected to the full battery of mutagenic analyses and correlations drawn between assay tiers for those substances. These analyses should include appropriate cellular, in vitro, submammalian and mammalian assay systems with particular emphasis on determination of the effective gonadal dose.

Task 2 - There is a need for development of non-destructive chemical fractionation methods to identify mutagenic compounds and prepare samples for further testing. Emphasis should be placed on testing of actual process mixtures and fractions rather than individual chemicals.

Task 3 - Improved methods for extrapolation of data from mutagenesis tests to accurately predict human genetic hazards are needed.

2.1.4.2 Effect of Coal Conversion Materials on Female Reproductive Capacity and Teratogenic Effects. Females of childbearing age may be exposed either as members of the workforce to fugitive emissions from coal conversion operations, or as members of the general population to emissions and effluents from the plant or from product combustion. It is necessary to determine the reproductive and developmental toxicity potential of the various complex mixtures and selected compounds associated with coal gasification and liquefaction. The developing fetus often shows an enhanced sensitivity to toxic agents. Therefore, these tolerances should be determined before permissible exposure limits are set.

Task 1 - Preliminary studies are required in laboratory animals to determine which process components would reach the reproductive organs and cross the placental barrier. The active forms of these materials should also be determined.

Task 2 - Animal toxicity studies should be conducted to determine the maximum tolerated dose by mother and fetus under both acute and chronic exposure patterns to coal conversion materials. This should include exposure by various routes, i.e., dermal, inhalation, ingestion, and intratracheal instillation. The newborn animals should then be followed for several months to assure that they are developing normally.

2.1.4.3 Effects of Coal Conversion Materials on Male Reproductive Capability. A number of organic chemicals, such as the pesticide DBCP, have been shown to affect male fertility. Workers, especially those involved in plant maintenance and cleaning, are most likely to be exposed most heavily to potentially toxic substances.

Task 1 - The various process mixtures to which workers are likely to be exposed should be tested to determine their toxicity to germ cells and their ability to cause reproductive hormone imbalances or loss of libido. Analysis of specific compound classes and interactions should be based on chemical characterization and the relative potential for human exposure to the various materials. Some test methods have been developed in this area for drug testing which should be adapted for use with coal conversion process materials.

2.1.5 Behavioral and Neurotoxic Effects

Human behavior can be affected by exposure to a wide variety of heavy metals, pesticides, organic solvents and noxious gases such as carbon monoxide and nitrogen oxides. Since coal liquefaction and gasification may result in worker exposure to many substances in complex mixtures, the potential for development of behavioral and neurotoxic effects should be evaluated.

2.1.5.1 Detection of Possible Neurotoxic Effects from Exposure to Coal Conversion Materials. Neurotoxic effects from chemical exposure, although uncommon, have long been known, e.g., exposure to lead and development of "foot drop." Since coal contains much nitrogen, there is a potential for formation of nitrogen-containing compounds. (A conceivable example is tetraethyl ammonium.)

Recent evidence that exposure to hexane and to methyl normal butyl ketone can cause specific neurotoxicological effects, raises concern regarding potential neurotoxicological effects that might arise from occupational exposure to the off gases from coal liquefaction and gasification. This concern is reinforced with the knowledge that carbon disulfide is one of the constituents of the off-gas.

To determine whether such effects may result from coal conversion process materials, animal tests are needed. These would include pathological study of nerve tissue, particularly when clinical symptoms have been observed. Any symptoms of neurological impairment manifested by abnormal behavior or actual neurological tissue change should be followed by special neurological studies. Workers in the coal liquefaction and gasification processes should be monitored under continuing medical surveillance that includes close observation for possible neurotoxic symptoms and signs.

Task 1 - Standard procedures should be developed to test samples, including liquids, gases and solids in animals for potential to cause neurotoxic effects such as peripheral neurasthenia. This should include methods for extrapolating animal effects to man.

Task 2 - The fuels and off gases from the coal conversion processes should be surveyed to identify those substances known to be neurotoxic. In addition, the process mixtures, emissions and effluents should be tested in animal systems to detect neurotoxic effects.

Task 3 - For those coal conversion process components shown to affect animals' performance under test conditions, analyses of animal neural tissues should be performed to detect anatomical biochemical neurological changes with a view toward increased understanding of neurological damage induction.

Task 4 - The results of the above two tasks should be correlated with clinical analysis of any worker in a coal conversion facility manifesting neurological changes as a result of exposure to coal gasification or liquefaction process materials.

2.1.5.2 Need for Testing Methods to Detect Behavioral Changes. Behavioral changes resulting from exposure to chemicals have been known for some time, e.g., alcohol, hallucinatory and other drugs, some solvents, trace metals, and pesticides. Standard animal testing procedures for identifying and quantifying such behavioral changes are just in the developmental phase. There should be expanded support for the development of such a testing methodology. Since these behavioral changes can be manifest among humans who are exposed, neurotoxicity testing should be included in the medical surveillance of persons working with and thus potentially exposed to such things as the off-gases of the coal liquefaction and gasification processes.

Task 1 - Testing procedures for identifying and quantifying behavioral changes in animals in response to specific chemical exposures should be improved and a standard testing protocol developed.

Task 2 - Observed behavioral changes should be correlated with anatomical and biochemical neurological changes with emphasis on increasing understanding of the underlying mechanisms.

Task 3 - The results of the above tasks should be used to design a clinical testing program for coal conversion workers capable of detecting behavioral changes manifested in workers.

Task 4 - A nerve cell screening system should be developed for rapid screening of coal liquefaction and gasification materials. The limits of the system with regard to predicting animal and human results and response to individual compounds versus mixtures should be determined.

2.1.6 Systemic Effects

Even though inhalation and dermal penetration represent the major pathways by which materials from coal conversion enter the body, the site or organs ultimately affected may be distinctly removed. For some substances, kidney or liver may be the primary target organ while other substances tend to accumulate in adipose or cardiac tissue or the brain. The toxicity of the various substances will be a function of dose of the chemical or its metabolites received, the exposure time, the organ systems affected and the potential for interaction with other chemicals.

Based on past experience with the coke oven and petrochemical industries, it is important to establish the toxicity of all effluents and products of the coal conversion process to which humans will be exposed. Toxicity data obtained from laboratory animals are an essential input for the prediction of the toxicity to humans of these various materials. These data will aid in assessing the degree of hazard under the spectrum of environmental conditions in the work place and at the consumption site. They will also aid in identifying necessary design modifications in commercial coal conversion plants and provide a basis for the establishment of appropriate handling procedures and safety precautions including possible exposure standards.

Because of the complexity and unknown biological effects of these mixtures, all systems should be evaluated in the course of such studies including the nervous, reproductive, respiratory, cardiac, integumentary, digestive, etc. These toxicity studies could ideally be a part of the carcinogenesis investigation.

2.1.6.1 Systemic Toxicity of Coal Conversion Materials. Workers engaged in conversion of coal to liquid or gas products, in delivery of these products to their ultimate destinations and the general public during product combustion may be exposed chronically via skin and inhalation to potentially toxic and biologically active substances. These substances include the liquid and gaseous effluents, fugitive emissions and/or solid waste products. Massive acute exposure to these same potentially toxic materials will also be possible during maintenance and repair operations and as the result of accidents.

Chemicals from solid waste disposal sites may also leach-out and subsequently enter the drinking water and the food chain, thus entering the body through ingestion. For these low-level pollutants to represent a hazard, however, gut transfer must occur. Some toxic substances are also concentrated as they pass up the food chain.

At the present time, data are not available on the systemic toxicity of the coal conversion emissions and effluents. While fragmentary data do exist on some of the polycyclic aromatic hydrocarbon components of these mixtures (1,2) and their metabolites(3-5) the data cannot be extrapolated to intact mixtures except perhaps to aid in designing experiments. It is important to develop dose response characterization of the the toxicity of the actual materials to which humans are exposed.

For many compounds the target organs are not yet known, nor is the actual route of transfer from lung, gut or skin to the target organ understood. In order to understand the nature of the toxic effects and to mitigate them, this type of information is essential. Ideally, a toxicity study should be designed to provide data on systemic, gross reproduction, carcinogenic, pulmonary, cardiac, dermal and behavioral effects resulting from chronic exposure.

Task 1 - Acute toxicity data on expected fugitive emissions, liquid and gaseous effluents, solid waste products and intact, and if appropriate, fractionated end products should be obtained in rats and mice using transdermal and inhalation routes. Attempts to identify the components responsible for the toxic effects should be made where complete prevention of workplace exposure to the mixture in question is not possible. While it would also be useful to obtain similar data on the oral and parenteral routes of exposure such studies would have a lower priority.

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Task 2 - Standard subchronic (3 months duration) studies should be performed in rats or mice on the same materials as in Task 1. Doses should be established on the basis of the results of acute experiments and from classical logarithmic extrapolation. Observations during the course of the study should include assessment of neurological function and behavior. At the conclusion of the study animals should be subjected to a complete hematology and clinical chemistry workup including liver and kidney function tests and a complete gross and histological examination.

Task 3 - Standard two year transdermal and inhalation toxicity studies should be performed on the substances mentioned in Task 1 in both rats and mice. Both sexes and pregnant females at several stages of pregnancy should be utilized. Doses should be established based on subchronic studies (Task 2). The battery of tests to be performed periodically during the exposure period should include, at a minimum, complete hematology and clinical chemistry evaluations and liver, kidney and cardiac function tests; appropriate additional endocrine, metabolic and biochemical studies should be performed as indicated by the observed effects. At the conclusion of the study all animals should receive complete hematology and clinical chemistry tests as well as gross and histopathological examinations.

Task 4 - Subchronic and chronic studies using the oral and parenteral routes of exposure should also be performed.

2.2 Occupational Epidemiology and Surveillance

The energy requirements in the U.S. are such that coal liquefaction and gasification technologies will be developed and expanded. These technologies contain in their process streams and end products, compounds that have the potential for causing cancer and other significant toxicological effects. Even though available control technologies will be installed in any new commercial-scale coal conversion facility, and interaction is likely to occur among the industrial hygienist, process engineer and design engineer during design and construction of the production facilities, exposures to materials associated with the process are likely to occur. Therefore, the exposed populations must be identified, the exposures characterized, and an evaluation performed to decide whether an increase of death or illness results from the exposures.

To determine whether increased use of coal gasification or liquefaction technologies will result in adverse health effects, it is necessary to conduct both retrospective and prospective epidemiology studies. To ensure that prospective data are maximally useful, it is desirable to collect the health data of all facilities in a similar format which facilitates later data comparisons. In addition, it is imperative to enlist the cooperation of all workers and their families in any prospective health screening program.

Coal liquefaction and gasification technologies may also require the development of more sophisticated personal and area monitors to detect the specific pollutants expected to be associated with these technologies. New indicator species may also be required.

Industrial hygiene procedures must be developed for these new technologies and presented to the employees in a manner which they can understand. Their cooperation must also be enlisted for carrying out medical surveillance and decontamination procedures.

2.2.1 Epidemiology

Historically in the United States there have been a number of small coal conversion plants; however the populations involved were small and only minimal records were kept. An exception was the coal hydrogenation plant at Institute, West Virginia, run by 359 employees of Union Carbide from 1952 to 1962. NIOSH has been following this occupational population to determine whether an initially observed increase in skin cancers resulted in increases in systemic cancers or other diseases. To date no unusual incidences of disease outside of the initial diagnosis and treatment of cancerous skin lesions have been detected. This study is of only limited use due to the small number of workers involved.

In addition to the Union Carbide facility, NIOSH is also investigating the Sasol Lurgi coal conversion facility in South Africa, and is negotiating a study to investigate the coal gasification facilities at Zagreb in Yugoslavia. They are hoping to determine any unusual disease occurrences through industrial hygiene records, worker interviews, medical record examinations and on-site studies.

Retrospective studies on these past and existing facilities are needed to identify any morbidity and mortality trends.

It is also important to initiate a prospective epidemiology program at all future U.S. liquefaction and gasification sites. The following kinds of medical surveillance observations are essential to epidemiological analysis for both the cohort and control groups:

- demographic characteristics
- medical data and histories including smoking and drug histories
- detailed occupational history
- pollutant exposure data

Such data need to be stored in a time-related fashion and the ability to cross-link and query the data base maintained. Such linkage requires standardization of the data items gathered and their definitions.

General population monitoring, even of populations living near gasification and liquefaction operations, is very difficult. There are some data available, however, through existing vital statistics records and disease registries such as those on cancer, heart disease and birth defects. There is a real need for development of new and novel methods.

2.2.1.1 Retrospective Study of Existing and Past Occupational Personnel. Data on the personnel employed at the coal conversion facilities in South Africa, East Germany and Yugoslavia are currently being sought by NIOSH. In addition, the 359 workers at the Union

Carbide facility in West Virginia should continue to be followed. It is only through a careful analysis of these existing exposed populations that any unusual disease occurrences will be detected, if they do in fact exist.

Task 1 - Establish a centralized registry to serve as a data bank for collection and analysis of data on persons employed in coal conversion facilities. The data from these foreign projects should be carefully evaluated and relevant conclusions drawn and published. This should be done within a time frame which permits use of these data in designing controls for new U.S. liquefaction and gasification facilities.

Task 2 - Conduct a detailed retrospective Epidemiology study at the Lurgi facility at Sasol, South Africa. Twenty years of medical records are available on both black and white employees. They should then be carefully reviewed to obtain meaningful statistical conclusions concerning the magnitude of potential occupational health effects associated with this process, one of those considered most commercially viable.

2.2.1.2 Prospective Epidemiology Study. Coal conversion technologies, to the extent used to date, have been reported to produce skin cancers, and analogous processes like coke manufacturing have resulted in excess incidence of lung cancer. Since coal conversion, especially liquefaction processes, produce fuels containing uncharacterized, high molecular weight, polynuclear aromatic hydrocarbons, the likelihood of their containing carcinogens is high. The coal dust associated with the coal preparation and the dust associated with char and ash disposal may also adversely affect the health of exposed workers.

In order to determine the nature of any adverse health impacts affecting the occupational population, a prospective epidemiology study should be designed to assimilate data from all coal conversion facilities as they begin operation. These data should be evaluated at a central location and collected in such a form that combined statistics for various sites and processes are obtainable. This ability to aggregate data is especially important during the early stages of the technology development when relatively fewer workers are exposed, but often to higher doses than during commercial operation.

Task 1 - An occupational health screening program should be designed for implementation at all coal conversion facilities. This would include medical history and data from employee physicals including data on smoking and other personal habits. Laboratory data and information from subsequent physicals should be added to the central file as well as disease incidence or disability claims. Monitoring for skin and lung lesions should receive particular attention; it may be necessary to analyze breath and urine for signs of chemical intake. Judging from experience with other industries, workers employed near boilers or hydrogenation apparatuses and maintaining this equipment are probably subjected to the greatest exposures, and should be followed most closely. This may mean that extra tests and exposure data (see Task 2) should be obtained for these high exposure individuals, or that they should be examined more often.

Task 2 - In addition to the personal medical history, detailed exposure histories should be collected. These should include job and station assignments by day, and an employment history. Any acute exposures should also be noted. Other exposures can be correlated later with data from personal or stationary monitors.

Task 3 - Workers are not obligated by law to participate in medical screenings, even when such examinations are required by the OSHA and MSHA laws. Medical-legal research is needed to assure workers that their records will be confidentially treated. Employees also need full guarantees of economic protection in cases where the medical findings dictate transfer to another job location due to occupationally derived health considerations. Only with these assurances will prospective epidemiological studies succeed in assembling the maximum available data.

Task 4 - All of the data on personal history, medical records and occupational exposure should be recorded at all coal conversion facilities in a standard format and be sent to a central location so aggregate statistics can be evaluated.

2.2.1.3 Epidemiology Studies of the Workers' Families and the General Population. Data which are available through vital statistics and disease registries on the persons living in the immediate vicinities of coal conversion facilities should be evaluated to determine whether the operation of the facility in this area has affected the general health of the community.

If community health problems are suspected, workers' families can be used in a retrospective study to see which age groups are most affected and the nature and duration of the effects. Workers' families may also be exposed to pollutants brought into the home on the workers' clothing or skin. These clothes may then affect those worn by other family numbers through common washing.

Task 1 - The standard sources of data such as cancer, disease and birth defect registries should be evaluated periodically for the areas surrounding coal conversion facilities to determine if any localized increases in morbidity or mortality have occurred. Where such registries do not exist, it might be desirable to initiate them or to help support existing registries in need of funding.

Task 2 - If the results of the above community screening indicate possible effects, the workers' families should be studied in closer detail. The families will reflect the broader age spans present in the community at large and will receive potentially higher doses through contact with the workers clothes and skin.

2.2.2 Industrial Hygiene

In order to protect the health of the coal conversion workers, use should be made of the knowledge of hazards associated with similar industrial situations such as those encountered in petroleum refining, coking and catalytic cracking. The liquefaction and gasification processes do present unique exposure situations, however, and for this reason monitoring and personal hygiene methods will require adaptation to this technology.

2.2.2.1 Monitoring. Monitoring is needed to identify and evaluate the existence of a health hazard, the effectiveness of engineering controls and consideration of process losses, to document exposure and identify contamination sources.

Since many coal conversion processes involve reaction of coal constituents and other chemicals under high temperatures and pressures, there will always be a potential for leakage of toxic gases and vapors into the occupational environment through seals, valves and vents, as well as the possibility of a major release of such toxicants during a process upset, pressure surge or pipe rupture. Many of the chemicals released under such conditions represent acute inhalation hazards, and can cause severe lung damage, asphyxia, and/ or death. Workers may be exposed to especially dangerous combinations of tars, chars and oils during startup, shutdown and maintenance so these periods should receive particular attention.

Two of the toxic gases which may be expected to be present in virtually all coal conversion processes at concentrations which can be immediately life threatening are CO and H_2S. Since CO is odorless, and H_2S rapidly produces olfactory fatigue after brief exposure at high concentrations, both can produce asphyxia without warning, and therefore can cause fatalities from exposure to process leakage as well as sudden releases. Continuous monitoring and alarm systems for these gases is needed in high hazard areas.

Similar hazards may exist where HCN, CS_2, COS, NO_2 and various metal carbonyls may be released, although these materials will generally be less likely to reach hazardous levels than H_2S or CO. In those specific process operations where they are likely to be released, continuous monitoring of atmospheric levels should be performed.

There is a particular need to provide improved methods for the routine evaluation of airborne cyclic organic compounds alone and in combination with other agents as they may be found in the work environment of a coal gasification or liquefaction facility. Existing methods of organic evaluation are often not quantitative, nor are there well-defined signature compounds.

The monitors for both inorganics and organics should be tied to alarm systems, and emergency evacuation procedures should be developed and tested to limit exposures and their health consequences.

In the event of a high exposure, methods are needed to expedite and facilitate evaluation of the body burden of the exposed employees. This may be done by analyzing urine and blood levels of compounds and their metabolites, but more work is needed to establish the dose/detection level/effect curves.

Task 1 - The determination of individual exposure histories of workers in coal conversion plants is especially difficult because most of the operations will be conducted out-of-doors. The instantaneous concentrations will vary greatly depending on the wind speed and direction as well as the proximity to the sources. Therefore, the only realistic way to accurately determine an individual's exposure is by using personal dosimeters and samplers. At present, however, dosimeters are available for only a limited number of chemicals, and personnel samplers operate at very low sampling rates, which limit the numbers and types of analyses that can be performed.

Personal monitors are needed which collect exposure data over an entire shift and are then subsequently analyzed. Existing monitors of this type can sample at rates up to 2 liters per minute which may be inadequate for some of the analyses required. The monitors should also provide an alarm if hazardous pollutant levels are encountered. This feature exists for CO and H_2S, two of the hazardous gases that will be associated with the coal conversion industry. It might be desirable to extend the personal monitor warning feature to include HCN or metal carbonyls which may also be present.

For currently available personal monitors for specific gases and vapors, data are needed on performance characteristics under various conditions of temperature and ambient pressure, and on the effects of co-contaminants on their performance. For those gases and vapors of interest where personal monitors are not currently available, data are needed on suitable performance and design specifications that must be considered in equipment development. Where alarm-type monitors are needed and not currently available, design and performance specifications are also needed. For personal samplers for the collection of samples for subsequent laboratory analyses, improvements are needed in several areas:

- development of improved sampling substrates and additional data on the performance of currently available substrates, specifically:
    a) data on sample collection efficiency
    b) data on sample recovery efficiency
    c) data on sample stability while on the substrate
    d) data on reactions among sample constituents
- development of samplers of improved performance characteristics especially with regard to sampling rate, reliability, size and weight
- storage of samples

Task 2 - Area-type monitors to enable determination of cumulative dosimetry, direct reading of concentration and emergency alarms are available for HCN, CS_2, metal carbonyls and NO_2. However, monitoring instrumentation for COS or metal carbonyls is not currently available commercially.

Task 3 - Current methods for analysis of complex polycyclic organic compounds in aerosols either involve specific compound identification or very nonspecific gross methods such as measurement of solvent solubility fractions in collected samples. Vapor characterization requires sample collection using adsorbers and subsequent degassing for compound identification. Quantification may be possible for specific compounds, but this approach tends to be more qualitative for complex mixtures.

Although it may be possible to identify signature compounds indicative of the levels of cyclic organic mixtures, because of the variations in these mixtures that may exist, the chosen signature compounds may not be present in proportion to the potential hazard under specific circumstances. It is therefore uncertain whether they represent an adequate surrogate.

It is therefore necessary to direct research to identify appropriate signature compounds for the coal conversion emissions. Sample compounds from each of the fuel cycle stages should be exposed to extensive testing to determine their biological activity (mutagenicity, carcinogenicity) and toxicity. If representative compounds can be found then they can be identified by monitoring systems. The currently used Benzo(a)pyrene indicator for polycyclic aromatic hydrocarbons does not seem to be an accurate predictor of biological activity, and an alternative should be sought.

Task 4 - Some of the most significant occupational exposures which will occur in the coal conversion industry will result from accidental releases associated with process upsets. Others will occur during maintenance operations, such as catalyst turnover, especially when work is done on process vessels and in other confined spaces. Since exposure atmosphere evaluations may not be possible at such times, it is necessary to have alternate means of detecting and evaluating such exposures. This can only be done by some type of evaluation of the exposed worker or on samples of body fluids such as exhaled air, urine, or blood.

Sampling of biological fluids of exposed workers is extensively utilized in a variety of industries. Its successful applications depend on an accurate knowledge of the metabolic transformations followed by the absorbed materials and the kinetics of these transformations. These data are essential to the proper interpretation of any sample analysis, since the concentrations of the material absorbed, their metabolic transformation products, and/or enzymes induced which may be analyzed all vary considerably with time following exposure.

For many of the organics, organometallics and some of the metal ions of concern in the coal conversion industries, the metabolic pathways and time constants needed are not currently available.

In order to use body fluids as exposure indicators the following kinds of information are needed:

- the chemicals of interest with respect to exposure evaluations
- the metabolic pathways of each chemical or mixture
- the kinetics of translocation and/or transformation of each chemical
- the effects of co-contaminants on the pathways and kinetics
- identification of the biological fluid(s) best suited for exposure evaluations
- identification of the chemical, metabolite or enzyme which provides the best indication of exposure and its intensity

2.2.2.2 Improved Skin Contamination Detectors. The current method for detecting the presence of polynuclear aromatic hydrocarbons, possible carcinogens, on the skin of workers involves detection with UV light. This introduces the potential for photoactivation of the compounds present on the skin surface. The risk is far less than being exposed to sunlight for a few minutes, but if alternative detection methods were available, this would add an additional margin of safety.

In addition to contamination detectors, the decontamination procedures should be studied to insure that workers are exposed only during working hours and that contamination is not carried home to the workers' families.

Task 1 - Research is needed on alternative methods to UV to detect the presence of polynuclear aromatic hydrocarbons.

Task 2 - Continued research is required on decontamination procedures for removing organics from the skin surface.

2.2.2.3 Worker Education. Often inadequate information is transmitted to the workers concerning the hazards to which they are exposed. In other cases the descriptions are too complex and filled with medical terminology to be easily understood. Workers should also be instructed in the operation and importance of personal monitors and the other procedures required to minimize their exposure to toxic substances.

Task 1 - Toxicological information, presented in lay terms, should be made available to the workers on all known potentially hazardous substances associated with coal conversion technologies.

Task 2 - Information on industrial hygiene practices must be made available to the worker. These should include descriptions of safe handling procedures, monitor operation and what to do in event of a spill or other accidental release. This information should be part of a preventive occupational health program.

Task 3 - A guidebook for plant management in the coal conversion industries should be prepared on the rationale and benefits of comprehensive preventive occupational health programs. Experience with exposures and control measures from the West Virginia Union Carbide coal conversion experience and from oil refineries should provide the basis for the design and planning of occupational exposure controls. Such operations as loading and unloading and maintenance should receive particular attention since accidental exposures and spills are most likely to occur at these times.

2.2.2.4 Noise. Since no commercial-scale coal conversion facilities are currently operational in the U.S., the extent to which noise will be an occupational hazard has yet to be accurately determined. However, both coal mines and oil refineries are quite noisy, and represent a hazard to the hearing of the employees. Occupational noise problems are well recognized today and are regulated to an allowable level of 90 dBA for an 8-hour exposure by the Occupational Safety and Health Administration (OSHA) and the Mining Safety and Health Administration (MSHA).

Task 1 - The potential for noise pollution should be carefully considered in the design of new facilities and if possible baffles, etc., designed right into the structures. If noise levels are still found to exceed allowable levels, ear muffs or plugs should be issued to the employees.

2.3 Safety Issues Associated with Major Process Accidents and Catastrophes

Catastrophes represent an important potential for exposure to workers and the surrounding population from direct exposure as well as contamination of foods and water. Despite the safety designs in plant construction and in operation procedures, catastrophic events may still occur and could cause exposure to various components of the process stream. These catastrophic events can include: (1) explosions and fires; (2) floods, tornados, hurricanes, and other natural calamities; (3) sabotage; and (4) accidental releases due to process upsets.

Additional potential exposures exist in the transport of products from plant to plant or from plant to the consumer. Potential exists for fires, explosions, spills, and exposures from cleanup activities. Tank farm storage of large quantities of synthetic gas or liquids can also present special problems regarding their location and operation.

Careful analysis of the process equipment and procedures in pilot plants needs to be conducted to identify the points where accidental hazardous exposures may occur. These weak spots require critical assessment when the toxicity of the materials present there is of concern. Feedback to the process engineer to correct any design deficiencies at these critical points is needed as part of the program.

An analysis of all potentials for catastrophes should be conducted for demonstration and commercial facilities. Control methods should then be developed and tested which would eliminate or reduce injuries to workers, or the general population, or those personnel responsible for cleanup procedures.

Included are problem statements addressing the accident potentials associated with the various coal gasification technologies and one dealing with fires which probably represent the major hazard, but which can occur at any stage from production to use of coal fuels.

2.3.1 Accidental Exposure to Coal Conversion Pollutants

There is the possibility of the catastrophic release of substances due to process upset, accidents, and sabotage. These could also involve the storage of fuels and wastes on site. Accidental exposures to these releases could adversely affect human health in the worker and surrounding general population. Transport of substances could similarly result in significant accidental releases which could also adversely affect human health.

2.3.1.1 Potential Accidents Associated with Coal Gasification. Though coal gasification processes have been in existence for a number of years and many of the vulnerable points for accidents are well known, a careful safety/accident analysis should be performed before the processes are allowed to operate at commercial scale. For gasification, the following stages are most likely to have catastrophic releases associated:

- gasifiers--possibility of fires
- gas (water) CO shift--potential overheat site, fire potential
- methanator--fire possible, could form nickel carbonyl (highly toxic) as it cools
- gas liquid separators--overflow could result in occupational exposure, fire hazard

Task 1 - For coal gasification options at the demonstration phase, the potential for accidents should be investigated and mitigating measures identified. The potential for nickel carbonyl formation following a methanator fire should receive particular attention due to its high toxicity (TLV = 1 ppb). Where possible accident situations are identified, safeguards should be built into the plant design. In addition, methods of evacuation of affected populations should be developed as well as cleanup methods and a registry of exposed individuals. Much data can be obtained from experience with similar processes like petroleum refining and petrochemical manufacture which will have a likelihood of many of the same types of accidents.

2.3.1.2 Potential Accidents Associated with Coal Liquefaction. For coal liquefaction the possibility of explosion associated with particle removal should be investigated and the potential for occupational hazard ascertained. In addition, the points where fires may occur should be identified and in the commercial scale plant these danger areas should be designated and control measures in place. For liquefaction these process stages may be susceptible to catastrophes:

- reactor-high heat and pressure--fire; explosion (H Coal)
- preheater--800°F--fire not explosion, controllable (SRC)
- filter--150 Psig & 500-600°F--explosive due to presence of volatile solvents under heat and pressure (SRC)

Task 1 - Up until the present time, domestic technology for coal liquefaction has been confined to pilot plants, but since similar operating temperatures and pressures will be used in commercial plants, adequate safety data should be obtainable. Based on the knowledge obtained from parallel industrial situations, measures for evacuation of affected populations, and cleanup are required. A registry of exposed persons should also be established.

2.3.1.3 Potential Accidents Associated with In Situ Coal Gasification. In situ gasification is only in the very developmental stages and the accident potentials associated with these processes need to be investigated. There is a potential for explosion and uncontrolled reaction during firing of a rubblized coal seam. Should fissures open to the surface during the rubblization, the potential for worker exposure to toxic gases would be extremely high. Exposures of workers underground are of similar concern.

Task 1 - As the technology progresses, control methods should be developed, tested and incorporated in the plant design. In addition an analysis of all possible accidents should be performed and alternatives established to deal with each type of situation.

2.3.1.4 Potential Accidents Associated with Transportation of Coal Conversion Products. Potential transportation accidents associated with movement of the product between processing plants or from the processing plant to the consumer must be examined. These include, but are not limited to explosions, spills, and exposures from cleanup operations. During a transport accident there is a hazard threat to the workers who must clean up the spill and to the general population. If the storm sewers (and surface water) are accidentally polluted the potential for human and ecological effects would be greatly increased.

Task 1 - Methods of cleanup/decontamination of the spill which will provide adequate protection of the worker and the community need to be reviewed and developed.

2.3.1.5 Potential Accidents Associated with Storage of Coal Conversion Products. Tank farm storage of large quantities of synthetic coal-derived gas and liquid are susceptible to large volume, low temperature fires in open air. Similar hazards exist for petroleum and petrochemical storage, but the nature of the chemical species present in coal conversion products may represent some unique hazards. Until the products themselves as well as the combustion products are characterized, their potential to cause effects cannot be assessed.

Task 1 - The following areas should be considered when determining the hazards associated with a coal conversion storage tank fire: acute and chronic toxicity, persistence, modifications of fire fighting procedures which might be needed, environmental cleanup measures, guidelines for storage facility siting and a registry of the exposed workers.

2.3.2 Hazards Associated with Fires at Coal Conversion Facilities

Fires may be associated with the production and processing of the flammable dusts, liquids and gases associated with coal conversion technology.

2.3.2.1 Fire Hazards. Fires may result in the release of aromatics like benzene and toluene causing intoxication and hindering worker escape from the site. There is also a high possibility of CO asphyxiation, or cyanide formation. Aldehydes such as formaldehyde or acrolein can form which are extremely irritating and toxic and may react synergistically with other off gases. Escape may also be hindered by heat and poor visibility.

Task 1 - The possible gases and liquids which may be produced as a result of uncontrolled combustion should be analyzed. Where the effects of these gases are unknown, animal toxicity tests are indicated.

Task 2 - The most likely conditions for fires should be identified and the nature of the off gases predicted. Based on these data, guidance for firefighters, containment procedures, cleanup of off gasses and liquids and community evacuation plans should be developed.

2.4 Balanced Basic and Applied Research Program

There are many specific research problems that arise from coal conversion which need to be solved in relation to health protection of workers and the general public. The solution of these problems will assist in selection of appropriate processes and engineering designs that will minimize health damage. At the same time, it would be a mistake to neglect those aspects of basic research that provide the foundation of understanding for the specific issues that concern coal conversion. For example, a central health problem in the coal conversion industry may well involve excess risks of cancer from contact with gasification and liquefaction products. The degree of protection required to provide adequate control of this health hazard is determined by our knowledge of dose-response relationships particularly at low levels of exposure where it is essentially impossible to obtain direct information by animal experimentation given the limited numbers of animals that it is possible to study. The only feasible approach to this basic issue is through our understanding of the dose-response patterns of components of the carcinogenic process and the nature of the carcinogenic reactions at the cellular and subcellular levels.

Another basic problem is that researchers rely on animal testing to give them primary information on agents which are likely to be human carcinogens. Information of this sort plays a major role in initiating regulatory action to control exposures to such substances. However, there is substantial uncertainty over the extent to which responses from animals are applicable to humans. There is a need to understand the basis for the differences in species susceptibility in order to develop more reliable assays for human carcinogenicity. An extension of this problem is the question of why some people are more susceptible than others to the action of carcinogens? This is known to be the case, but little information exists about the basis for such differences. Methods are needed to identify and protect individuals who are susceptible to the action of carcinogens before they are exposed.

These are a few examples of basic research problems whose solution would have a tremendous impact on our ability to effectively control health hazards from the coal conversion industry. The solution to these problems is not going to come from explicitly defined testing protocols, but from a sustained and adequate level of support for basic research not only in carcinogenesis but also in other important areas related to coal conversion such as reproduction toxicology, including mutagenesis and teratogenesis, and behavioral and neurotoxicological effects.

3.0 PRIORITY RANKING OF PROBLEM AREAS

Once the Health Effects subpanels had defined the individual problems and research requirements within each of the larger problem areas, the whole panel was reconvened to review the products of the subpanels. Individual suggestions were incorporated and the panel endorsed the subpanel outputs as correctly representing their viewpoints.

In order to obtain an indication of the priority the panel would assign to the various problems, a voting procedure was implemented. The panel members were asked to rank the importance of each of the ten problem areas on a scale of four from high(1) to low.(4) They were asked to base their decisions on the potential seriousness of the problem, and the current state of knowledge, but not on the costs associated with the research. The results of this priority ranking are contained in Table 3-1.

It is interesting to note that, despite the different backgrounds and research interests of the panel members, there was a high degree of concurrence on the nature of the highest priority problems. The panel members felt that the potential for release of carcinogenic substances required investigation, even though the actual hazards may be no higher than those from conventional coal or petroleum refining operations. The carcinogenic risks required quantification to determine whether increased controls are required, or whether more engineering research is needed to make coal conversions acceptable from a health viewpoint.

TABLE 3-1

PRIORITY RANKING OF HEALTH PROBLEM AREAS*

	PROBLEM AREA \ PRIORITY	1 HIGH	2	3	4 LOW
Toxicological Effects	Carcinogenesis	11	1		
	Systemic & Dermal Effects	6	5	1	
	Pulmonary Effects	6	5	1	
	Genetic, Reproductive and Developmental Effects	4	5	1	
	Behavioral and Neurotoxic Effects		7	4	1
Occupational Health	Occupational Epidemiology and Surveillance	8	1	3	
	Monitoring & Evaluation of Occupational Effects (Exposure)	7	4	1	
Occupational Safety	Castastrophes	4	1	3	3
	Accident Control-Fire	3	2	3	4
Basic Research	General Planning for Basic Research	4	4	2	1

The panel also felt that occupational safety and surveillance research should receive emphasis because it is through a correlation of exposure levels and observation of effects that health problems are most likely to be identified. Increased attention should be focused on the occupational rather than the general population since they receive greater exposures and are more likely to develop subsequent health effects more rapidly. Included in these tasks is also the need for development of worker protection measures. The benefits from this research come both from a lowering of risks due to exposure and from an increase in information on cause-effect relationships for a broader array of chemical substances.

The remainder of the research areas received much less support. Obviously, if funding is available in levels sufficient to amply cover the carcinogenesis and occupational health and surveillance activities, any additional resources should be directed toward the other research areas. It should be remembered that a number of research results in these areas for coal conversion would be highly applicable to other fossil fuel technologies, so funding at a low level under several technologies could be combined to support a more generic research program.

The preference order of the projects did not change when weightings were included to give more emphasis to high than middle or low scores. This leads to the conclusion that distribution of scores was consistent across project areas.

WORKSHOP ON THE HEALTH AND ENVIRONMENTAL EFFECTS OF COAL GASIFICATION AND LIQUEFACTION

August 20 - 25, 1978

Report of Air Quality Panel

INTRODUCTORY REMARKS

The panel considered the impacts on air quality of the emissions from coal liquefaction and gasification technologies. Emphasis was placed on the airborne transport and transformation of emissions associated with the various components of the energy cycle. The panel was not primarily concerned with occupational exposures, which were the responsibility of the Occupational and Public Health and Safety Panel. Instead, the Air Quality Panel concentrated its activities on pollutants that might cause adverse effects beyond the fencelines of the coal conversion facilities. An exception is in the modeling area, where a specific recommendation was made related to atmospheric modeling of exposures to outside air within the fenceline of facilities.

A number of chemical species which may be judged of possible concern in occupational exposures in work areas were not considered by the panel to be of significant concern in community atmospheres. For example, no special efforts were considered justified on the composition of metallic elements. For most elements, the community exposures were estimated to be too low to be an air quality problem. An exception might occur where char with a high concentration of elements will be used as a fuel (e.g., synthane, HYGAS), rather than coal in a steam boiler, associated with a coal conversion facility.

The panel carefully reviewed the process steps with source characterization experts and sought to pinpoint the critical unresolved problems associated with emissions which might adversely impact on air quality on a local or regional scale. Both the process stream losses and the steam boiler emissions were of concern, depending on the pollutant under consideration.

Both measurement and modeling problem needs were identified. In some situations, the best possible combination of measurement and modeling technology will be needed to differentiate the emissions from a coal conversion facility from the baseline air quality from all other existing sources.

End-use problems were not addressed. For example, at this time, it was not considered appropriate to consider the consequences of the use of the coal liquefaction product as a vehicular fuel.

Past Accomplishments

During the last years, a number of existing energy sources have been investigated in terms of airborne transport and transformations. Substantial resources have been allocated to problems in this area by the Interagency Energy/Environment R&D Program. One major component of project MISTT (Midwest Interstate Sulfur Transformation and Transport) involved measurements of sulfur oxides, nitrogen oxides, ozone and aerosols within coal-fired power plant plumes. Plumes were sampled from aircraft out to 300 km. The conversion rates for sulfur dioxide were obtained, deposition rates estimated and total sulfur budgets obtained. Production of aerosols was consistently observed downwind. Ozone deficits were observed in fresh plumes, but excess ozone was observed in some experiments well downwind. It was demonstrated that the narrow nighttime plumes were decoupled from the surface and traveled substantial distances overnight, i.e., the high wind speed region aloft. The results of the project MISTT were reported by several groups of investigators at the International Symposium on Sulfur in the Atmosphere, at Debrovnik, Yugoslavia, in September 1977, and published (Atmospheric Environment, Vol. 12, No. 1-3, 1978).

Another group of field projects was conducted involving the effects of both isolated petroleum refineries and petrochemical industrial complexes on air quality downwind. Excess ozone formation was observed from the petrochemical complex emissions and in some of the plumes from isolated petroleum refineries. Such plumes are characterized by being hydrocarbon-rich, that is, these plumes contain a large excess of hydrocarbons over nitrogen oxides.

Separate source characterization studies have been conducted by numerous investigators on the flue gases of coal-fired power plants and industrial boilers. Sulfur oxides, nitrogen oxides, hydrochloric acid, sulfates, the distribution of elements by particle size and other characteristics of such flue gases have received substantial attention. The effects of fuel, operating conditions and control device efficiency have been delineated.

There are similarities between the emissions from existing coal-fired power plants, coking ovens, and petroleum refineries and the emissions associated with coal conversion facilities. Most of this past effort has been directed at large utility facilities, rather than the smaller steam boilers (with an estimated maximum size of 300 megawatt equivalent), which will be operated in conjunction with coal conversion facilities.

Problem Areas Identified

Seven problem areas were identified as of high or medium priority in air quality. These problem areas can be separated into three categories:

I. Pollutant emissions of potential air quality concern associated with process stream losses.

II. Pollutant emissions of potential air quality concern associated with the steam boiler.

III. Improvement and validation of air quality simulation models to predict the impact of coal conversion facility emissions on scales ranking from within 1 km (within fenceline) to several hundred kilometers from such facilities.

Based on the current stage of development of in situ processes, it was concluded that any air quality problems associated with that technology would develop at a much later date than those related to the aboveground methods. Thus, efforts of the panel concentrated on aboveground techniques.

Review of the process steps in aboveground coal liquefaction and gasification indicated that there are strong commonalities in the types of chemical compounds present. Thus, the pollutants can be considered without separate reference to liquefaction or gasification in defining air quality problem areas.

The process steps of specific interest vary somewhat, depending on the pollutant of concern. They include the off gases from pretreatment and the coal lock hopper; unincinerated vent gases from acid gas removal; the potential for volatilization of a number of organic and gaseous inorganic species from the aqueous condensates circulating in cooling towers; leaks from valves, flanges, pump seals and other points in the process hardware; and sudden losses during equipment failures. The substances identified as of particular concern to air quality include the following:

A. Volatile photochemically reactive organic vapors which can contribute, when mixed with nitrogen oxides, to formation of ozone and other products downwind.

B. Potentially toxic organic materials in the form of finely divided aerosols. These may be either primary or secondary (i.e., formed in the initial process or during subsequent transformation).

C. Gaseous carbonyl sulfide (COS).

D. Phenolic and other toxic organic vapors.

E. Sulfur oxides, nitrogen oxides and total suspended particulates.

The first four groups of substances are primarily associated with process stream losses, while the fifth group is predominantly associated with the steam boiler emissions.

The problem areas associated with the development of air quality simulation models for emissions from coal conversion in complex terrain conditions or in complicated industrial-urban settings are, by far, the most resource-intensive areas considered. It is important to note that such models would have applications to many important emission sources. Joint funding by the agencies involved in this program area in government and industry (Electric Power Research Institute and Gas Research Institute) would be advisable.

Individual Air Quality Problem Areas

This section of the report will briefly discuss the individual air quality problem areas identified as of high or medium priority interest.

Problem No. 1

Losses of volatile organic substances which are photochemically reactive can occur from coal conversion processes (pretreatment of gases, leaks, cooling tower losses). In particular, reactive volatile organic chemicals may be emitted in unincinerated vent gases from acid gas removal. They may also be emitted from leaks in valves, flanges and other fittings. Contributions of these reactive organics to ozone formation and possible formation of toxic products upon photodegradation should be investigated.

Coal conversion facilities are potential sources of atmospheric pollutants. These atmospheric pollutants may include not only inorganic compounds such as SO_x, NO_x and CO, but also hydrocarbons. These organic substances can react with the nitrogen oxides and sulfur oxides emitted from the steam boiler to produce ozone, peroxyacyl nitrates, other oxidants, aldehydes, cresols, sulfate aerosols, nitrate aerosols and organic aerosols well downwind. They may also be toxic or may produce toxic products when photo-oxidized. The identification of these organic compounds, their emission rates, their atmospheric cycles and their degradation products is necessary if the impact of coal conversion facilities on air quality is to be assessed. No measurements are available to demonstrate such secondary reactions downwind of coal conversion facilities. When the facility would be imbedded in an industrial-urban complex, rather than in an isolated location, substantial effort would be required to separate out the contribution of the coal conversion facility from all other contributing sources.

Emissions data from existing conversion units are extremely necessary. If there are no data, then several other studies can be undertaken to obtain information that can be used to predict emissions from new coal conversion facilities. Specific existing oil refineries can be investigated and their emissions monitored. These refineries need to be selected carefully, since coal conversion units are estimated to produce greater percentages of aromatic-type hydrocarbons than the average refinery. New coke oven facilities could also be investigated in order to determine their emissions. After establishing the emissions from either existing foreign coal conversion facilities or by drawing analogies with refineries and coke oven facilities, it is necessary to determine the reactive compounds of the hydrocarbons and other organic compounds at various expected compound/NO_x ratios. This information can be obtained from smog chamber studies and through theoretical and experimental calculations involving reactions of the emissions with OH, HO_2, RO_2 and O_3. Information on secondary aerosol production will also be needed, since reduced visibility may be associated with the emissions from the coal conversion facility (Air Quality Problem #2). It is also necessary to determine the baseline air quality of the area before the proposed coal conversion unit is in operation. Synergistic effects arising from the interaction of the emissions of the unit with other pollutants already in the area must also be investigated.

The types of emissions, their rates of reaction with OH, HO_2, RO_2 and O_3, and a study of their production formation, will help in understanding the importance of these emissions to the local and regional air quality, in general, and to the downwind formation of ozone, in particular.

Only pilot-scale or laboratory bench-type units are currently in operation in the United States. Data are available in the literature on these bench-type operations. Some modern commercial operations exist outside the U.S., but no information is available on the emissions from these facilities. It would be most desirable to collect air samples from at least one of these foreign facilities (e.g., Westfield, Scotland, South Africa, Yugoslavia).

Specific research projects which would be undertaken are:

1. Field studies of foreign coal conversion plants in order to obtain information on emissions and air quality downwind.

2. If (1) is not possible or limited, conduct field studies of selected refinery(ies) and coke oven(s) judged to have emissions similar to coal conversion facilities.
3. Conduct smog chamber studies on emission products obtained in (1) or (2) at the most probable HC/NO_x ratios expected.
4. Determine basic rate constant data for the reactions involving the exotic organic compounds found in (1) or (2) above with OH, HO_2, RO_2 and O_3.
5. Conduct modeling studies on data obtained in (1) through (4) above in order to determine the effects of such emissions on air quality. (This would be a box-type chemical model study which would not duplicate or overlap any of the modeling studies described in air quality problems 6 and 7.)

To complete all of the projects in this problem area would require an estimated 5 years of effort involving 12 to 16 person years, along with equipment and computer time costs totaling $1.0 million to $1.5 million. This problem area was rated as high priority.

No critical new health data needs could be identified beyond those assumed to be available from ongoing projects. No unique measurement development needs are identified specifically with this problem area.

Problem No. 2

Many coal conversion processes produce potentially toxic organic tars. Possible losses of potentially toxic organic tars can occur in off gases from the pretreatment stage, leaks and equipment failures. These substances may be in the form of primary organic aerosol emissions, organic aerosols formed by adsorption or organic vapors on solid particles or by atmospheric reaction of some types of olefinic hydrocarbon vapors. Organic aerosols may cause adverse health effects and can contribute to visibility reduction. Chemical characterization of these tars is necessary before precursor compounds can be chosen for evaluation in smog chamber studies. Smog chamber studies are needed to verify aerosol formation. Ambient background characterization is required before estimates can be made regarding impact of operating a coal conversion facility in a particular area.

Little data is available on the analysis of tars from full-scale coal conversion facilities. Perhaps some information on tar composition could be obtained from the analysis of coal tars produced in coking operation. Some projects are underway or in the planning stages, whereby carbon, organic particulate and vapor-phase organics will be studied in the Ohio River Basin.

Data are required on the modes of formation, chemical composition, physical properties and biological effects of organic aerosols. The potential for primary and secondary organic aerosol formation should be investigated downwind of commercial-scale units abroad. Baseline measurements of organic aerosols are needed in areas of the United States which are likely to be selected as construction sites for coal conversion units. Little monitoring data are available because such measurements cannot be made routinely.

Health effects information on organic aerosols (except for some polynuclear aromatic hydrocarbons as particles) is extremely limited. There have been few, if any, atmospheric studies allowing correlation of organic aerosols with either health or visibility parameters.

Improved sampling and analysis techniques should be developed for organic aerosols. Techniques capable of being used in routine monitoring programs are needed. Similarly, improvements in bioassay techniques to provide more sensitivity should be developed.

Specific research projects which should be undertaken are:

1. Obtain coal conversion process tars from full-scale operational plants in Kosavo, Yugoslavia and/or Westfield, Scotland and determine their chemical composition.
2. Determine coal conversion tar reduction products and reaction rates using smog chamber studies.
3. Evaluate and improve existing sampling and analysis techniques and establish state-of-the-art procedures for collecting and analyzing ambient levels of phenols, cresols, naphthalenes, pyrenes, aza arenes, thiophenes, etc.
4. Improve the sensitivity of bioassay techniques to the point where ambient-level trace organics can be assayed on samples collected over reasonably short time periods.
5. Determine the impact of using different coal types and conversion processes on tar chamical composition.
6. Perform ambient background studies in areas slated as potential sites for coal conversion process plants.

To complete the various projects proposed would require about two years of effort involving 20 person years and about $1.5 million. This program area was rated as of high priority.

Problem No. 3

Carbonyl sulfide (COS) is emitted from several steps in the coal conversion process stream (lock hopper, unincinerated vent gases from acid gas removal). The health effects of occupational or long-term ambient exposures to COS are uncertain. In addition, this is a stable molecule in troposphere, with a lifetime estimated to be in excess of one year. Thus, global concentrations may increase and there is the potential for adverse environmental effects, e.g., an effect upon the chemical and/or radiation balance of the stratosphere. If the flue gases from the acid-gas removal stage are not incinerated, coal conversion facilities may emit COS in concentrations up to 20 percent of the total atmospheric sulfur emissions from the plant. As discussed above, there may be adverse direct health effects and/or global environmental effects. In order to assess the significance of these risks, the following issues need to be addressed:

1. What information, if any, is available on occupational or long-term, low-level exposure to COS?
2. What is the global background level of COS?
3. What anthropogenic sources exist now and what are their estimated emission rates?
4. Are there natural sources of COS?
5. What is the tropospheric lifetime of COS?
    - How valid is the assumption that the homogeneous reaction, OH and COS, is the predominant sink?
    - What are other potential sinks?
6. What are the mechanisms of photodissociation and reactions of COS and what is the influence on stratospheric SO_x, O_x, HO_x and NO_x cycles?

Measurements are needed to define source and ambient air concentration levels of COS in urban and background ambient samples to aid in locating and estimating the importance of other anthropogenic and natural sources. It has been suggested that COS can be transported to the stratosphere, thus contributing the sulfur found in aerosol form in the lower stratosphere. In view of the experience with chlorofluorocarbons, it appears prudent to investigate the fate of all substances which have longer lifetimes in the atmosphere. It is only by assessing the other sources of COS that it can be determined whether coal conversion emissions will contribute a significant increment. This problem was rates of medium priority.

A survey of the health effects data on COS is needed, with appropriate recommendations if current data is inadequate. Although research techniques do exist to measure carbonyl sulfide, these procedures tend to be too complicated for use in the workplace or for ambient air monitoring. Reference standards are needed for COS to establish the reliability of measurements being made.

Existing data on COS is very limited. The significant limitations and data gaps are given below:

1. Availability of health data unknown - may not exist.
2. Complex techniques for measuring COS are available for special studies. For measurements in the occupational and workplace environments, some methods development is needed. No measurement standards exist.
3. Only semi-quantitative measurements of COS have been made. The estimated non-urban value is 600 ppt.
4. The anthropogenic versus natural contribution to global COS is unknown.
5. Volcanos and forest fires have been suggested as natural sources, and petroleum refineries and synthetic fiber plants as anthropogenic sources.

6. The OH and COS rate has been determined within a factor of five and identified as the predominant gas phase sink. Based on the OH rate, the reactive lifetime in the troposphere is approximately 500 days. Nothing is known about other potential sinks.

7. Little information is available on stratospheric processes. The flux of COS into the lower stratosphere is uncertain. Carbonyl sulfide has been postulated to contribute to the stratospheric sulfate layer.

Specific data and information required is as follows:

1. Survey of available infomration on health effects of COS. This is a recommendation to the health panel.
2. Measurement techniques and standards for source and ambient concentrations.
3. Measurement of global background concentrations.
4. Determination of existing anthropogenic and natural sources and their emission rates.
5. Determination of anthropogenic versus natural contributions to the global budget.
6. Evaluation of potential sinks other than the OH plus COS reaction.
7. Identification of data gaps in stratospheric chemistry of COS and generation of data, as required.

The data and information obtained will be pertinent in the following ways: Item 1 is required to determine whether the potential of health risks exists and if further health studies are required. Items 2 - 6 are required to determine whether COS emissions from coal conversion facilities can contribute significant concentrations to the global budget. Item 7 is required to determine the potential of adverse stratospheric effect. Some of these data requirements are contingent upon the findings of others. For example, health data may be available, in which case additional studies are not required. If it is determined that coal conversion can contribute little to global COS levels, detailed studies on stratospheric chemistry are unwarranted.

In order to obtain the required data and information, a five-part research project is needed:

1. Survey of data base on health effects of COS and further studies, as required. This project is a recommendation to the Health Panel.
2. Measurement program for COS, including development of reliable analytical techniques for the ambient and workplace environments, development of reference standards and measurement of mean global concentrations.
3. Estimation of the total flux of COS into the atmosphere and determination of whether coal conversion facilities can contribute a significant fraction to this flux. Determination, where feasible, of anthropogenic and natural emission rates and evaluation of other potential sinks.
4. Determination of natural versus anthropogenic contribution to the global budget via techniques such as carbon-14 isotope analysis.
5. Survey of available information on the photochemistry and reactions of COS and photodecomposition products under stratospheric conditions. Generate data needed to understand effect of COS on the SO_x, HO_x and NO_x cycles.

It was estimated that a five-year program of research would be needed to investigate all aspects of this potential program. About 20 person years of effort involving a total minimal effort of $1.0 million is justified. This level of effort does include some, but not all, of the work on measurements, but none of the health-related effort.

Problem No. 4

Losses of volatile, potentially toxic chemicals to the atmosphere can occur from the aqueous condensates in cooling towers associated with coal conversion facilities. The chemical and physical characteristics of volatilized species should be measured. The initial phase of this would involve laboratory studies of bench-scale systems. These would be followed by field studies of appropriate cooling tower emissions downwind. Specifically, one is concerned about release of species such as phenolics, residual low molecular weight organics and possibly HCN, H_2S and COS. The questions are: what species are volatilized and at what sorts of concentrations?

Aqueous scrubbing waters and steam condensates will be employed following at least primary water treatment for the purposes of cooling. Based on present information about the probable composition of treated aqueous effluents of this type, one would expect some residual organic species, many of which may be toxic, to be present in cooling waters. The stripping action of the cooling operation may then remove these species to the atmosphere either as gases or possibly as liquid aerosols.

Specific sub-problems would involve determination of the components present in treated process waters from different treatment operations; secondly, identification of both the physical and chemical forms of species actually removed to the atmosphere; and thirdly, determination of the contributions of such vaporized species to the total plant emissions.

Very little pertinent data exist at present, due to the lack of cooling waters which have been produced from treated coal gasification waters. Specific data gaps are identified below. In addition, it should be stressed that data are needed regarding the end products of several water treatment processes as applied to process waters:

(1) What chemicals are present in cooling waters following several proposed levels of water treatment?

(2) Which species are actually volatilized and in what forms are they aqueous?

(3) Do species volatilized from cooling towers undergo chemical changes as a result of the stripping process?

(4) Do the volatile emissions from cooling towers contribute significantly to overall plant emissions?

(5) Can any of the compounds volatilized produce an environmental impact (e.g., health, odor, weather, etc)?

The information required relates directly to the problem insofar as it would establish: (1) whether volatilization really occurs; (2) what components are actually volatilized; (3) whether the amounts are significant; (4) whether an environmental impact is indicated; and (5) what counteractive measures might be considered.

A five-part research project is proposed:

1. Literature survey to identify probable process water treatment compositions and to identify potentially volatile species therein.
2. Experimental field determination of major/minor chemical species present in cooling waters.
3. Determination of conditions required for volatilizing different chemical species.

4. Determination of physical and chemical characteristics of volatilized species and of the changes which they may undergo when emitted.

5. Determination of the contribution of species volatilized from cooling waters to the overall plant emissions.

The laboratory-scale investigations could be accomplished in three years. If appropriate towers and cooling waters become available, a field investigation would require an additional two to three years. The resources involved would be eleven person years and a total cost of $0.85 million over a five-year period. This problem was rated high priority.

Problem No. 5

Emissions of SO_x, NO_x and total particulates from steam boilers in coal conversion facilities will contribute to the ambient concentration of these air pollutants within a region. Consequently, they will increase the potential for visibility degradation, acid rain and health effects.

Coal conversion plant are energy-intensive facilities, consuming 20-30 percent of the total coal energy input for internal use. About two-thirds of this (i.e., 13-20 percent of the total coal energy) is used in the production of process steam, with the remainder lost to system inefficiencies. In current coal conversion plant designs, steam generation boilers are either totally coal fired or use process char to supplement the coal feed. In the latter case, total coal energy consumption is obviously reduced somewhat. It is expected that the emission characteristics of the totally coal-fired units would be similar to existing coal-fired power plant boilers of comparable size. The current boiler designs for coal conversion include both electrostatic precipitators and scrubbers for the removal of flyash and SO_2. However, even with the installation of these control devices, the steam boiler is likely to constitute the main source of SO_x and particulates for the coal conversion facility. For example, in the case of a WESCO Lurgi coal gasification design, about 90 percent of the particulates and 65 percent of the SO_2 are attributed to the steam boiler equipped with precipitator and scrubber (reference MITRE M78-58). There is no reason to believe that other conversion processes would have boiler emissions which were much different.

The expected close similarity between the proposed steam boiler emissions and existing power plant and industrial boilers provides an unusually good opportunity to draw upon the existing data base. Since 1974, an extensive interagency R&D program pursued a study of transport, transformations, removal and overall impact of power plant emissions. In general, the existing data would be applicable to steam boilers of coal conversion facilities within the following framework:

1. There is no need for coal characterization beyond the ongoing work.
2. The design and operating conditions of coal conversion steam boilers are likely to be somewhat different from power plant boilers. These different conditions (e.g., combustion temperature) will probably influence the composition of the effluents (e.g., NO_x).
3. The specific meteorological dispersion parameters need to be determined for each proposed plant (related to Problem No. 7).

4. The primary pollutants, SO_2 and NO/NO_2, undergo chemical transformations in the atomsphere, which lead to the formation of more harmful substances such as H_2SO_4 and HNO_3. The mechanisms and rates of these transformation are not well understood at present, but the ongoing research will clarify these problems within the next five years.

5. The transformation rates of SO_2 and NO/NO_2 to secondary pollutants depend on the reactivity of the background air. For each proposed coal conversion facility, therefore, the transformations of primary to secondary pollutants need to be assessed, considering the ambient concentration of reactive species from other sources.

6. The deposition rate of air pollutants depends on parameters such as rainfall frequency and intensity, the nature of the vegetation and soil, the vertical mixing, etc. It is believed, but not yet confirmed, that in arid western U.S. areas the deposition rate would be lower than in the eastern U.S.

In order to assess the air pollution impact of the steam boiler, data are required on:

1. Chemical and physical characteristics of the coal (e.g., sulfur and ash content).

2. Design and operating characteristics of the boiler, precipitator and scrubber, including stack height, flue gas emission rate and temperature.

3. Meteorological parameters determining the plume dispersion.

4. Parameters determining the transformation of SO_2 and NO/NO_2 to more harmful secondary pollutants.

5. Rates of and mechanisms for removal of pollutants from the atmosphere, including geographical and seasonal variations.

In summary, the existing information and data base, as well as the ongoing research on the fate of gaseous power plant effluents, are sufficient to satisfy a large fraction of the research needs for boiler impact analysis. However, the two projects described below would be desirable:

1. The bulk of the existing data pertain to large, 1000 to 2000 megawatt, electric utility power plants, usually in an isolated setting. Special field and meteorological/chemical modeling studies should be conducted at existing power plants and/or industrial boiler installations that have similar characteristics (size, site, surrounding emission pattern) as the proposed coal conversion steam boilers. This effort is estimated to require about $500,000/year for three years, or a total of 20 person years and $1.5 million.

2. One of the weakest areas in the current understanding of the fate of power plant of steam boiler emissions is the removal of pollutants from the atmosphere. Laboratory and field studies should be conducted to improve the current level of knowledge on the rates and mechanisms of the deposition process. The studies should consider the overall averages, as well as the spatial and temporal variation of deposition rates and the chemical composition of the deposited material. This project would require $500,000/year for five years, or a total of 33 person years and $2.5 million. The problem of the fate and impact of steam boiler emissions is rated of high priority.

Problem No. 6

The exposure level to potentially harmful pollutants from coal conversion plants needs to be determined for occupational personnel working in outside areas within the fenceline of the facilities. Both the short-term (hours) and long-term (years) hazards need to be determined by applying a modeling approach.

Downwash and fumigation conditions are crucial to short-term effects. Incidences of air stagnation and the effect of advection on radiation fogs (sulfurous smog) must be known. Short-term plume chemistry and deposition of solids must be considered. Long-term exposure levels should be determined on the basis of plant configuration and wind rose data (for plume trajectory averaging). A climatology of atmospheric conditions must be obtained for one or more potential typical sites. In principle, this overall problem is analogous to that of estimating ground-level concentrations for plumes from conventional industrial stacks. It is also similar to the problem of estimating carbon monoxide levels in "street canyons."

Existing models are reasonable in a qualitative sense for flat terrain, neutral stability and constant wind conditions which, unfortunately, exist only a small percentage of the time. Requirements for ground-level versus elevated source emissions will differ. Data on fumigation or downwash conditions and for realistic plant configurations are approximated best with physical simulation (aerodynamic) models. Confidence in model predictions must be derived from efforts to validate the dispersion of plumes and fugitive emissions from existing industrial plants. Therefore, some information should be drawn from existing case study results in order to determine refinements to the models for coal conversion applications.

Data on emission heights and plant dimensions will be needed in analytical and physical simulation models. At what plant locations might one expect fugitive emissions to escape into the air? Plume particle-size distribution and physical properties must be known before scavenging and deposition estimates can be given. Climatologies for several typical sites are needed for the short- and long-term, which include winds, precipitation and mixing height, or atmospheric stability and incidences of fogs and cloudiness. Once specific sites are selected, models should be applied to characterize ground-level emissions at those sites.

Two specific projects which should be considered are:

1. For typical plant dimensions and layout, estimate ground-level concentrations using physical simulation models.
2. Development and application of analytical models for short-range concentrations for conditions other than flat terrain, neutral stability and constant wind conditions.

The resources needed involve 15 person years and a total cost of $0.75 million. This problem was rated as of medium priority.

Problem No. 7

This problem is concerned with the entire issue of improving and establishing the reliability of air quality simulation models over a wide range of distances for two particularly difficult conditions: (1) complex terrain and (2) coal conversion facilities imbedded in industrial-urban complexes. Because of the magnitude and nature of their emissions, coal conversion plants have the potential to violate air quality standards. Because of their likely operation in coal fields that are within regions of pristine lands, they also have the potential to violate the very stringent regulations for prevention of significant deterioration. In its present state, the mathematical simulation of atmospheric transport and diffusion (as well as transformation and depletion) is far from the state of reliability that is required. For example, for the relatively simple and optimum situation of flat terrain and steady meteorological and emission conditions, model validation is generally within a factor of two at downwind distances of a few kilometers. For settings in complex terrain where many coal fields and/or urban-industrial configurations are located, simulation models are frequently beyond a factor of ten or more. Air flow that is dominated by terrain features is typically considered as exceptional in the view of current modeling technology. In reality, terrain-dominated flow is significant in most real situations. Some specific subproblems are: (1) uncertainty about the deformation of streamline flow around and over obstacles, including the separation of relatively smooth flow from an irregular surface, often with chaotic turbulent flow in the underlying layer; (2) inability to realistically model slope flows (e.g., up and down valleys) and combinations of slope flows that develop in response to local density gradients as a consequence of diurnal heating and cooling near the ground; (3) lack of ability to define the local circulation during stagnation episodes (e.g., in deep valleys when the macroscale pressure pattern is weak); (4) difficulty in realistically modeling plume impaction in elevated terrain--such phenomena are capable of causing exceptionally high concentrations at ground-level; (5) a requirement to model enhanced convection/instability that results from differential heating of variously oriented surfaces of irregular terrain; and (6) the difficulty of formulating models that include sufficient details to be realistic on the one hand and, on the other, are sufficiently practical in terms of high-speed computer requirements. In addition, while the problems of modeling atmospheric transformations and depletions of pollutants are not restricted to complex terrain, they are significant aspects of the overall modeling effort that deserve continued research support.

Extensive information is available that documents irregular air flow over complex terrain. Although much of this information is qualitative, there is no doubt that such flows occur frequently. However, their full magnitude and frequency of occurrence are unknown for many particular types of complex flows. The types of data required to understand and to adequately model air flow over complex terrain are those obtained from full-scale, three-dimensional field studies and from scaled physical model studies that employ wind tunnels and water channels.

A comprehensive research project having three main parts must be implemented in an integrated, interactive, ongoing mode that continually builds on its own overall progress. These main parts are: (1) Complex Terrain-On-Site Experimental studies that provide measured data in three dimensions of atmospheric structure and the response of tracer systems on overall scales that extend through at least a full diurnal cycle (e.g., hundreds of kilometers). The spatial density of the required measurements range upward from tens of meters in the vertical to hundreds of meters in the horizontal. The temporal density requires measurements averaged over times at least as small as one hour. Such measurements should be obtained using conventional as well as more recently developed techniques, including remote sensors such as acoustic sounders and laser doppler sounders carried on mobile platforms; (2) Scaled Physical Modeling Studies that simulate transport and diffusion over complex terrain. Such studies require the use of two fluids because of scaling requirements. One employs air in a wind tunnel to simulate conditions in which local surface temperature differences do not affect the flow (e.g., near-neutral stability conditions). The other employs water in a channel to simulate conditions in which temperature structure does affect the flow (e.g., stable or inversion conditions); and (3) Mathematical Model Development that continuously interacts with (1) and (2) by suggesting experimental scenarios and using such experimental data to validate the models. A major objective is to generate models that are practical in terms of computer resources (e.g., by parameterizing physical processes), that provide the necessary detail resolution and that are reasonable in terms of input data requirements. Two basic distance scales are applicable. These are the local scale, about 1-30 kilometers, and the regional scale, extending beyond 100 kilometers. The model must be capable of providing concentrations averaged over periods ranging from one hour to one year. The bottom line of model development is to establish credibility, which can be accomplished by incorporating error and sensitivity analyses into the developmental program.

The field studies are necessarily complex and costly because of the high density, spatial and temporal extent (a full diurnal cycle) of both the air quality and meteorological measurements needed. The need for measurements aloft requires extensive use of aircraft and remote sensing techniques. The mathematical modeling effort would be conducted as an integrated ongoing part of the field studies and the wind tunnel and water channel studies.

This project at several sites over a five-year period is estimated to involve 150 person years and a total budget of $25 million to $30 million ($5 million to $6 million per year). Because of the high cost of this project, it would be reasonable to approach the funding as a joint activity involving several government agencies and the several institutes established industry to fund research on fossil fuels and their health and environmental effects. This problem area is rated as high priority.

WATER QUANTITY, QUALITY AND ECOLOGICAL EFFECTS

1.0 INTRODUCTION

The Workshop on The Health and Environmental Effects of Coal Gasification and Liquefaction Technologies was sponsored by The Interagency Committee (Department of Energy, Department of Health, Education and Welfare and The Environmental Protection Agency). The primary objective of all panels was to anticipate and identify problem areas and research needs associated with the development and commercialization of these energy technologies.

The Water Quantity, Quality, and Ecological Effects Panel was concerned with identifying potential impacts on aquatic resources resulting from development and implementation of coal gasification and liquefaction technologies. In some cases insufficient data were available to justify separation of gasification from liquefaction and, hence, these technologies were treated together. Some of the major concerns of the panel included availability of water, transport and fate of inorganic and organic substances produced or mobilized by the conversion process or effluent disposal, and the potential ecological effects resulting from chronic low-level exposure to effluent components. Based on these areas of concern, the panel was divided into the following subpanels: water quality and quantity, aquatic transport and fate, and ecological effects. The individuals who contributed to each of the subpanels are identified in Table 1. Each subpanel was responsible for identifying specific problem areas and research needs.

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Table 1

Water Quantity, Quality and Ecological Effects

Panel Participants

Individual	Organization	Subpanel
K. E. Biesinger	Environmental Protection Agency	co-chairman
W. J. Birge	University of Kentucky	ecological effects
J. A. Black	University of Kentucky	ecological effects
D. L. Britt	Flow Resources Corporation	water quality and quantity
A. L. Buikema	Virginia Polytechnic Institute and State University	ecological effects
J. W. Falco	Environmental Protection Agency	aquatic transport and fate
C. W. Gehrs	Oak Ridge National Laboratory	chairman
J. M. Giddings	Oak Ridge National Laboratory	ecological effects
S. E. Herbes	Oak Ridge National Laboratory	aquatic transport and fate
E. P. Krug	Department of Energy	water quality and quantity
C. R. Moxley	Gulf Mineral Resources Company	aquatic transport and fate
M. J. Schneider	Battelle Northwest Laboratory	ecological effects
A. D. Shepherd	Oak Ridge National Laboratory	water quality and quantity

Potential direct aquatic problems associated with the operation of above ground coal conversion processes arise from atmospheric and aqueous effluent releases, from residue disposal requiring land utilization, from product and process spills and from consumptive water use by the facility. Atmospheric releases were considered lowest in priority with respect to direct aquatic effects, although indirect effects such as acid precipitation may have substantial implications to water resources and aquatic productivity. Consequently, much more information on composition, transport and deposition of atmospheric releases is necessary before an adequate assessment of the role of coal conversion in acid precipitation can be made.

Direct stack emissions from synfuels processes pose little hazard for aquatic environments although cooling tower drift and deposition may give rise to both terrestrial and aquatic problems. Cycling of contaminated process water through cooling towers coupled with the practice of chlorination suggest the potential for release of exotic organic and chlorinated organic compounds about which little is known.

Although direct aqueous discharge may be kept to a minimum, insufficient data with respect to waste treatment capabilities exists. Data are also quite meager with respect to transport and effects of the various types of organics that might be chronically released to aquatic environments. Consequently, aqueous discharges remain high in priority as potential sources of impact on aquatic environments.

Product spills, both at the plant and during transportation, will probably result in the major source of organic loading to aquatic environments. Substantial land will be dedicated to the ultimate disposal of solid and semi-solid residues. The dearth of knowledge concerning the composition, mobility and fate of these materials led the panel to place high priority on development of a data base to enable assessing these materials.

Initial discussion of in situ gasification suggested that the aquatic problems would be similar to those faced with in situ oil shale development. The reader interested in this topic is directed to the document prepared on oil shale for a complete discussion of that technology. In general, problems would involve groundwater contamination from combustion zones and surface subsidence. Groundwater contamination may result from mobilization and/or leaching of trace elements, inorganic salts, and organics (e.g., phenols, aromatic hydrocarbons) from the combustion zone. Subsidence may disrupt flow patterns of underground aquifers, having major effects upon future water availability.

The remainder of this document is composed of the three subpanel reports. Each includes a description of the subpanel's focus, a summary of the issues that must be resolved to assess the potential hazards of coal conversion technologies, and an evaluation of the data currently available concerning these issues.

2.0 WATER QUANTITY

Water availability will be a prime consideration in regional energy planning, the siting of facilities, and design of process options for both coal liquefaction and coal gasification technologies. Although commercial-scale coal liquefaction facilities generally will consume more water than gasification plants, the problems of water availability are common to both technologies. For the purposes of the present discussion, these two fossil technologies will be treated as a unit.

The water requirements for coal conversion technologies depend on: the type of coal utilized, the process options employed, the cooling systems and water recycling technologies used, the requirements of the labor force and induced development, and the environmental characteristics at the site of development. These factors need to be integrated so that process options and water conservation strategies can be optimally selected for specific regions of commercial development.

The availability of water may be a problem in both the eastern and western regions of the United States, but the extent to which the problem may affect technology development is markedly different in the two regions.

Many western regions receive only about one-fourth or less of the surface precipitation present in the East. Additionally, stream flows often exhibit much larger seasonal fluctuations, which leads to water availability problems, especially during low flow conditions. Western water laws also form a rigid framework for determining actual water supplies available to any user or group of users. The appropriation doctrine of water rights recognizes seniority of water rights claims as a class of property rights. Since some streams in the West are already overappropriated, many (if not most) coal conversion facilities will be forced into trying to purchase water rights from existing users. In some areas where water is simply not available, interbasin transfers of water, subject to state approval, may be considered.

Other factors which will impact on water availability are the quantities of water which will eventually be reserved for Indian lands, Federal lands, and for instream flow requirements to maintain water quality and aquatic biota. Water for agriculture, which accounts for over 80 percent of water consumption in the West, is the most logical candidate from which to attempt to acquire water through purchase of water rights or by increased expenditures to improve irrigation efficiency.

Although much of the East is considered a "water rich" area, cumulative water consumption has been projected to cause localized water shortages within the next decade. Present water quantity data are not generally available at a level of detail to predict localized low flow conditions in many eastern regions. The possibility that more eastern states will adopt minimum instream flow standards also may affect current water supply projections.

To evaluate the impacts of coal conversion technology development, analyses of local and regional water supply and demand and water management techniques are needed. Though the problems differ in magnitude between the East and the West, very similar issues must be considered. The problems identified by this panel include the need to quantify the amount of water available both as surface and ground water during an average year and during periods of low precipitation. Instream flow requirements need to be established to protect aquatic biota, especially during low flow periods. The availability of water for coal conversion will also be dependent on the laws governing water rights. In general, water rights are governed by the doctrine of appropriation in the West and riparian rights in the East, although, the laws of each state vary. For all coal conversion technologies approaching commercialization, the amount of water required by the associated processes must be accurately determined. Finally, the environmental and socioeconomic impacts resulting from diversion of water from agriculture or industrial uses to energy production must be analyzed.

2.1 Problem Statement: Quantity of Surface and Groundwater Available

The quantity of existing surface and groundwater needs to be assessed to determine if an adequate supply of water will be available for the development of coal conversion facilities. Net availability of water is a function of existing natural flows, existing water rights of other users, and water resource management practices.

Data on surface water flows are available from several Federal and state organizations. Likewise, reservoir storage capacity data exist for most regions. However, both stream gaging and reservoir impoundment data require further analysis to estimate water availability during low flow periods. The supply of groundwater is not well known for most areas; information is lacking in terms of recharge rates and sustained annual yields. Information on water resource management practices may be available from states, Federal agencies (e.g., U.S. Geological Survey, U.S. Army Corps of Engineers, Water Resources Council, Bureau of Reclamation), river basin commissions and other regional organizations.

In portions of the western U.S. where water is already too scarce to meet existing needs, the addition of coal conversion facilities with their concomitant water needs will only increase the need for maximal management of water resources.

In the East, county-level or some similarly appropriate scale analysis estimates of surface water availability are needed to assure minimal instream flows.

The following tasks are applicable to eastern as well as western water availability problems.

Task 1. Existing water analysis methods, models and information need to be extended to quantify and map streamflow during average and low flow periods.

Task 2. All existing data from USGS, states, etc., on groundwater storage and well yields should be assembled. Models of the possible contribution from groundwater to augment streamflow and surface storage should be constructed; feasible pumping rates and ground water recharge phenomena should be determined.

Task 3. There is a need to investigate water rights to determine the availability and extent of unused or unappropriated stream flow and surface water in reservoir storage.

Task 4. The operating rules and management plans for reservoirs and river basins should be surveyed and evaluated to determine if additional water could be provided by more effective management practices. Seasonal fluctuations in the various water basin uses need to be determined. Functional reserve storage capacities and methods for obtaining additional supplies of water (e.g., reservoir development, interbasin transfer of water) need to be investigated.

Task 5. More detailed information and projections are needed for competing water uses. Presently water use data are only available at the Water Resources Council aggregated subarea level. Proprietary county water use projections by sector may be available and could be utilized.

2.2 Problem Statement: Consumptive Water Use Requirements

Water requirements for coal gasification and liquefaction technologies depend upon the process options and water conservation technologies employed, and on the environmental characteristics of the site. In addition, the domestic water requirements associated with the construction and operational labor force, as well as adjacent, induced, residential development may have significant impacts. Regional characteristics such as climate, the nature of the raw coal, the general water quality and quantity and the types of industries existing in the area must be considered.

In order to assess and project the regional and local impacts of commercial synfuel production, the total unit water requirements, within an estimated range of error, need to be established. The water needs will vary depending on the technology option. Figures are available in the literature for the water requirements of various process options; however, discrepancies are numerous. At least one report has projected water requirements that might be incurred at three different sites involving several different process options and recycling systems. Additional work of this type is needed.

Task 1. The unit water requirements for the most likely commercialization candidate coal conversion technologies need to be projected on a site and regional basis. These water requirements should include specific information with estimated error ranges for the following parameters: net process water, cooling system requirements, losses in products, by-products, and residuals; domestic requirements for labor force and induced development; and mining requirements (if a mine-mouth facility is the probable configuration).

2.3 Problem Statement: Establishment of Minimum Instream Flow Requirements

The consumptive use of water by coal conversion facilities may result in significant deterioration of downstream water quality. Total dissolved solids may become concentrated and salinity may be increased by the reduction in flow caused by water withdrawals for coal conversion facilities. In many western regions, evaporation of water used for irrigation purposes has resulted in increased salinity of existing water.

Instream flow requirements must be developed and/or refined to assure the protection of aquatic biota and the maintenance of downstream water quality. Methodologies have been developed for determining flow requirements necessary to protect critical aquatic organisms and communities and to maintain water quality. However, these methodologies need further evaluation and refinement since most appear too general to assure protection of aquatic ecosystems.

Task 1. Existing and proposed standards for minimum instream flow requirements need to be surveyed.

Task 2. Improved methodologies for establishing minimum flow requirements necessary for maintaining aquatic ecosystems need to be developed.

Task 3. Determine if the operation of coal conversion facilities will allow for maintenance of minimum instream flows. This should be done as part of the site selection procedure.

2.4 Problem Statement: Legal and Institutional Constraints on Water Use

Existing and potential legal and institutional constraints on water use need to be identified to determine if water will be available for the development of coal conversion facilities. Very little information on appropriated water rights is available in an easily utilized form.

Under the riparian water law doctrine followed in most of the eastern U.S., the owner of riparian land has the right to "reasonable" use of the surface water in connection with the use of the riparian land. "Reasonable" use is very loosely interpreted in most cases to mean not interfering with other riparian users downstream, although precedent gives domestic users the highest priority. Industrial water use, including energy development, generally has a relatively low priority. Furthermore, in response to environmental concerns, some states have or are considering establishing minimum flow criteria, which would restrict or prohibit consumptive water use from streams during low flow conditions. Major questions are therefore raised regarding water supply and low flow augmentation from existing and proposed reservoirs and from ground water sources to insure a reliable alternative source during seasonal droughts.

In the West, water rights are determined by a different set of criteria known as the appropriation doctrine of water rights. Under this system, water rights are considered a class of property, separate from real property, which may be bought and sold. In the West, water rights for coal conversion uses will have to be purchased from current owners. The western states have not yet defined their position on granting transfer of water rights to coal conversion industries. Existing and potential Federal and Indian reserved water rights have also not been quantified or considered in many of the water availability estimates.

Task 1. For the western states, research identifying the legislative and institutional restrictions on the purchase and transferral of water rights needs to be integrated into the siting analyses to determine if water rights can be purchased and transferred to coal conversion industries.

Task 2. The effects of Federal and Indian reserved rights on present water supplies and future appropriations should be investigated.

Task 3. For the eastern states, research surveying the laws and practices governing water uses should be integrated into siting and assessment studies. This will provide the background to determine the legality of water restrictions governing maintenance of streamflow and the principles to be followed in deciding among competing water users for the available resource.

2.5 Problem Statement: Social and Economic Impacts

There may be social and economic impacts associated with changes in water use, especially in the western U.S. Because water is limited and the doctrine of appropriated water rights exists, energy interests will need to purchase water rights from other water users. It is anticipated that water will be diverted from agricultural uses to use by coal conversion industries. This change in water use could significantly alter the socioeconomic characteristics of the region by elimination or dislocation of food production and industries related to agriculture.

Task 1. Integrated assessments should be conducted in regions which may have significant alterations in water use caused by coal conversion industries. These assessments should identify changes in community structure, demography and agricultural productivity. They should also consider the possible escalation in water rights value and the possible need for desalination procedures.

3.0 AQUATIC TRANSPORT AND FATE

Aqueous effluents from coal conversion facilities are likely to contain a variety of contaminants. These contaminants may reach both surface and ground water in the region surrounding the facilities and result in a decrease in water quality. Releases of aquatic effluents may be both intentional, as in the case of discharges from wastewater treatment facilities, or unintentional through spills or process malfunctions.

The objectives of the aquatic transport and fate subpanel were: (1) to identify major potential pathways for introduction of contaminants from coal conversion plants into natural waters; (2) to identify major transport processes which govern behavior of contaminants once they have entered natural waters; and (3) to identify research required to assess contaminant transport behavior. In dealing with pollutant transport behavior, the panel considered only those issues likely to be associated with coal conversion technologies.

The panel considered the potential for pollutants to enter the aquatic environment during each stage of the major coal conversion processes, but certain process steps were considered to have the greatest possible impact. Leaching of contaminants from landfill disposal areas was considered a major potential problem associated with the coal conversion technologies. The potential transport of contaminants into surface waters from combustion of synthetic liquid fuels was also considered because the types and levels of trace organic contaminants produced are likely to differ from those produced during direct combustion of either coal or fuel oil. In addition to the direct introduction of contaminants from aqueous discharges, other potential sources of contaminants were identified, including accidental spills of liquefaction products into water bodies and rainout or watershed runoff of contaminants which have been released to the atmosphere. Leaching of materials from coal piles was not considered because this is a problem associated with existing coal combustion technology.

Once the contaminants have entered surface or ground water, they will be subject to a variety of transport and transformation processes. It is important to realize that the types of transformation processes will be affected by the classes of contaminants released, their concentrations and characteristics of the receiving water (e.g., pH, temperature, salinity, flow rate). For example, salts and trace metals may precipitate or sorb to suspended or bedded sediments, whereas trace organics may be altered by photolysis, volatilization or microbial degradation.

The processes which transport, transform, concentrate or remove contaminants form the critical link between what is actually released in the discharge and the potential for adverse effects on aquatic organisms or humans. If transport rates of toxic contaminants are low, or rapid degradation to nontoxic forms occurs, potential health and ecological impacts will be restricted to small areas near the source. Conversely, if transport rates of toxic substances are high, or degradation occurs slowly, potential health and ecological impacts may occur over large areas.

At the present time, there is little quantitative information on the contaminants which will be released from coal conversion facilities. However, the subpanel recognized that organics and inorganics (including trace elements) would all be present as potential contaminants (see Tables 2 and 3). Characterization of the pollutants discharged will be necessary before ultimate predictions can be made of the types of transformation processes which will occur.

The Problem Statements specify tasks required to characterize the fate and transport of pollutants in ground and surface waters. This fate and transport information is necessary to estimate the concentrations of pollutants in ground and surface waters surrounding production and product user facilities. Integration of these concentration estimates with appropriate health and ecological effects data should provide a basis to determine potential health and ecological impacts.

3.1 Problem Statement: Leaching of Contaminants from Landfill Disposal Areas

Disposal of sludge, slag and ash presents a potential long-term source of pollutants which may be transported to ground or surface waters. Among these pollutants may be toxic substances which can adversely affect aquatic biota and contaminate drinking water supplies. If contaminated water is used for the irrigation of crops,

TABLE 2
ORGANIC COMPOUNDS IDENTIFIED IN LIQUID EFFLUENTS FROM COAL CONVERSION TECHNOLOGIES

Compound	Gasification	Liquefaction
acetaldehyde		X
acetic acid		X
aniline	X	
anthraquinone	X	
benzaldehyde	X	
benzene	X	X
benzofuranol	X	
benzonitrile	X	
cresols (m,o,p)	X	X
ethylene glycol	X	
formaldehyde		X
methyl indole	X	
methyl mercaptan	X	
naphthalene	X	X
naphthols	X	
phenanthrene	X	
phenols	X	X
pyridines	X	
pyrocatechols	X	
thiophenes	X	X
toluene	X	X
xylene (m,o,p)		X
xylenols (2,3;2,4; 2,5;2,6;3,4;3,5)	X	

Adapted from: Pellizzari, E.D., 1978, Identification of Components of Energy-Related Wastes and Effluents, EPA-600/7-78-004, pp. 12-20.

TABLE 3
ELEMENTAL COMPOUNDS IDENTIFIED IN LIQUID EFFLUENTS FROM COAL CONVERSION TECHNOLOGIES

Trace Elements or Inorganics	Gasification	Liquefaction
Al	X	
Ammonia	X	X
Ammonium cyanate		X
As	X	
Arsenic Acid, Na salt	X	X
Ar_2O_2	X	X
Arsine	X	
Ba	X	X
$BaCl_2$		X
Be	X	
B	X	
Br_2	X	
Ca	X	
$CaCl_2$		X
CaO	X	
$CaSO_4$		X
Cd	X	X
$CdCl_2$		X
$CdNO_3$		X
Cs_2	X	
COS	X	X
Cl_2	X	
Cr	X	
Co	X	
Cu	X	
Cyanides	X	X
Fe	X	
F	X	X
Ge	X	
HCl	X	
HCN	X	X
HF	X	
H_2S	X	X
Hg	X	X

TABLE 3
ELEMENTAL COMPOUNDS IDENTIFIED IN LIQUID EFFLUENTS FROM COAL CONVERSION TECHNOLOGIES (CONCLUDED)

Trace Elements or Inorganics	Gasification	Liquefaction
K	X	
Mg	X	
$MgCl_2$		X
MgO	X	
Mn	X	
Na	X	X
NiCO	X	
P	X	
Pb	X	X
Sb	X	X
Se	X	X
Sn	X	
Sr	X	
Te	X	
V	X	X
U_2O_5	X	X
Zr	X	X

Adapted from: Pellizzari, E.D., 1978, Identification of Components of Energy-Related Wastes and Effluents, EPA-600/7-78-004, pp. 21-26.

pollutants may also be introduced into food supplies. Only limited data are available to predict transport of pollutants from landfills.

The rate of leaching is of critical importance in estimating the rate of pollutant transport from solid waste disposal sites. In addition to the leaching rate at the source, the rate of movement of pollutants will be dependent on adsorption and ion-exchange characteristics of each constituent, the porosity of the soil, and bulk movement (rate of transport of water in the soil). For materials which move large distances, spread of contamination may be governed by diffusion, particularly in directions perpendicular to the direction of flow. Where diffusion is important, differences in the molecular diffusivities of constituents may cause materials to separate.

Characterizations of the landfill and of the sludge, slag and ash material are required to estimate the rates of pollutant leachability. Estimates of soil/water partition coefficients for each constituent or each class of constituents are required to determine the retention of these materials as they move with groundwater. Estimates of molecular diffusivities of each constituent or class of constituents are necessary to estimate the movement of materials by diffusion. In addition, estimates of soil porosity and groundwater movement are needed to define the rate of bulk transport in these systems.

Methods for determining soil/water partition coefficients are available, but specific data exist for only a few substances, mostly pesticides. Of these available data, a moderate amount is available on heavy metals and inorganics, but very few data are available on hydrocarbons. Empirical and semi-empirical correlations are available to estimate the molecular diffusivities of compounds; a moderate amount of data exists on direct measurements of diffusivities. Soil characteristics and groundwater movements have also been studied but most of the information is presented for other purposes. Rates of pollutant leaching from different types of landfills are probably available at least to a limited degree. These existing data should be evaluated for application to coal conversion waste landfills.

Task 1. Characterization of the physical condition of landfill material is necessary. This should include a description of the state (e.g., finely divided particles, compacted solid, ceramic) of the sludge, slag and ash. The chemical composition of the fill material should also be determined; emphasis should be placed on quantifying water soluble constituents. The design of the landfill should be specified. Estimates of the rate of leaching from the landfill should be based on lab leaching tests and landfill design characteristics. These estimates should be verified by field studies which measure leaching during the first six months to one year of landfill operation and periodically thereafter. Leaching estimates reported in the literature from other landfill sites should also be examined. However, differences in fill materials must be considered when extrapolating from literature results.

Task 2. The physical/chemical properties of contaminants which are leached from the landfill should be determined. Literature surveys should be conducted to collect all available measurements of diffusivities and soil/water partition coefficients for all identified constituents. Correlations should be used to estimate diffusivities of constituents which dissociate in water. Measurements of diffusivities will be required for those contaminants which are leached from the landfill and dissociate in water. If information on soil/water partition coefficients is not available in the literature, these will need to be measured for each site-specific soil type.

Task 3. For each site, the porosity of the soil in the vicinity of the landfill should be determined. Elevation of the groundwater table and the rate, direction and velocity of groundwater flow are required as well.

Task 4. A survey of existing groundwater transport models should be conducted. The models should be evaluated to determine the extent of modifications necessary for application to the localities surrounding proposed coal conversion sites.

3.2 Problem Statement: Aqueous Discharge of Organics

The release of trace organics in aqueous discharges from coal conversion facilities may prove to be an environmental hazard. Several of the trace organics anticipated to be released are known carcinogens. Low levels of these organics in drinking water or edible fish flesh may constitute a human health hazard. It is anticipated that these organics could be released at levels which may be toxic to aquatic organisms. In order to determine the extent of potential adverse effects, the transport and transformations of trace organics released need to be determined.

Task 1. Since hundreds of trace organics may be released at very low levels (parts per billion), it will be necessary to establish a system for grouping these organics into chemical classes by molecular or physical characteristics. This will enable priorities to be assigned for sampling classes of organics. For example, several classification schemes have been proposed for trace organics which distinguish polycyclic aromatic hydrocarbons (PAH's) and nitrogen containing PAH's as high priority classes.

Task 2. The quantities and characteristics of trace organic classes discharged in treated effluents from demonstration coal conversion facilities need to be determined. Estimates should also be made of the quantities and frequencies of unplanned releases of trace organics from spills or process malfunctions.

Task 3. The rates of transport and transformation processes for representative compounds from each class of potentially hazardous trace organics released need to be measured. Organics may be transformed by physical/chemical processes such as photolysis, hydrolysis, volatilization and sorption. These processes as well as biotic processes such as microbial degradation and bioaccumulation need to be investigated. Variables such as suspended solids, pH, light, temperature and flow may also affect transport and transformation processes and should be considered.

Task 4. For each coal conversion facility, a monitoring program to measure the levels of trace organics in the water, sediments and biota in the vicinity of the plant site should be established. Site-specific hydrological data should also be collected. The baseline monitoring program should begin at least one year before plant construction.

Task 5. Existing transport models which predict the movement and fate of trace organics in the aquatic environment need to be adapted by using the information obtained from Tasks 1-3. The model should be verified by using the results of the monitoring program (Task 4).

3.3 Problem Statement: Emissions from Combustion of Liquefaction Products

It is anticipated that trace contaminants will be released during combustion of liquefaction products. Since liquefaction products are more highly aromatic than standard boiler fuels, combustion may result in emissions of polycyclic aromatic hydrocarbons and other potentially hazardous compounds into the atmosphere. These trace contaminants may adsorb to the surface of small aerosol particulates and travel for some distance before settling out. The primary aquatic concern involves the potential for contamination of water bodies due to rainout of these particles.

Task 1. The levels of trace organic and inorganic contaminants released to the atmosphere during combustion of liquefaction products need to be determined. Since very little is known about the levels of polycyclic aromatic hydrocarbons emitted during combustion or formed in the plume, these should be characterized and quantified. Particulate material should be characterized to determine the leachability of contaminants from the particles.

Task 2. Air plume dispersion and settling models should be revised and applied to estimate the rates of contaminant precipitation and rainout into surface waters.

3.4 Problem Statement: Accidental Spills of Liquefaction Products

With the emergence of a major coal conversion industry, it is anticipated that there will be an increase in the transportation of liquid fuels by barge, tank car, and tank truck. As in the case of petroleum-derived fuel transportation, the potential exists for accidental spills on water. Mathematical models which predict the transportation, dispersion, and deposition of petroleum material in a receiving body of water currently exist. However, due to differences in chemical composition, for example, phenolic content, higher gravities or lower viscosities, it is unlikely that these oil spill dispersion models could be applied directly, without modification, to liquefaction end products.

Certain chemical and physical properties of liquefaction products are known from existing pilot plants. This information is limited in that product properties are a function of the type of coal used. There is also a lack of data concerning diffusion coefficients, rates of deposition into sediment, and water/oil surface tension properties. These types of data are required to adapt existing models to predict the dispersion of accidentally released liquefaction products in the aquatic environment.

Task 1. The parameters required as input to dispersion models need to be defined. Since the following properties will affect dispersion in water, they should be determined for liquefaction products:

- water/oil surface tension
- phenolic content
- rates of biodegradation, photolysis, evaporation and deposition
- specific gravity, viscosity, solubility in water and other physical properties; and
- dispersion coefficients vs. the tendency for agglomeration

Properties of the receiving water body (e.g., pH, flow rate, salinity) will also affect dispersion and should be determined.

Task 2. Existing "cleanup" procedures for oil spills should be evaluated to determine if they are applicable to spills of liquefaction products.

3.5 Problem Statement: Airborne Release of Contaminants

The transport of trace contaminants from airborne releases into nearby surface waters may present a health hazard both to aquatic organisms and to humans through their drinking water. Trace organics and trace metals may be released in cooling tower drifts and fugitive plant emissions. These contaminants may then enter waters either directly through settling of particles, aerosols and rainout of volatiles or indirectly through watershed runoff.

Task 1. The total release rate of contaminants into the atmosphere needs to be determined. This task includes identification and quantification of contaminants released from cooling towers and measurement of the levels and forms of contaminants present in fugitive plant emissions. Specific research in this area will probably be suggested by both the source characterization and air quality panels.

Task 2. The direct entry of airborne contaminants into waterbodies and the deposition of contaminants within the watershed need to be determined. Air dispersion and deposition models are available, but they will need to be modified for adaptation to coal conversion atmospheric releases. This problem will be addressed in more detail by the Air Quality Panel.

Task 3. The rates of transport and transformation of contaminants deposited on the soil need to be determined to predict the mobility of contaminants through the soil into surface and/or ground waters.

3.6 Problem Statement: Aqueous Discharge of Trace Elements

It is likely that aqueous discharges from coal conversion process streams will contain various trace elements including heavy metals. Reported trace elements include antimony, arsenic, boron, bromine, cadmium, fluorine, lead, mercury and nickel. The exact concentration and form (complexed, redox state, etc.) of the various trace elements discharged will be dependent upon the resource, the process and the control technology employed. While in the aqueous environment, the trace metals can undergo further reactions/transformations depending on their physical/chemical properties and those of the medium. Metals vary in their toxicity and biological reactivity depending on the valence state. These trace metals may accumulate in sediments and may prove toxic to aquatic organisms.

Although effluents containing trace elements have been recognized as potential problems for some time, little research has been directed toward obtaining a clearer definition of the issues involved. At the present time there are:

1) No data on the effect of anticipated wastewater treatment procedures on trace element levels.

2) Little quantitative data on metal concentrations in raw wastewater.

3) No data on element form (dissolved vs. particulate), chelation, or redox state, although models have been developed to predict equilibrium levels of chemical species as a function of redox, pH, temperature, etc.

4) No estimates of non-planned aqueous releases.

5) Some data on metal availability from sediments and from the water column, although the form of metals in coal conversion effluents may be different, thus altering uptake by aquatic organisms.

Task 1. For each resource (coal type) and process, trace element contaminants in the aqueous discharge streams must be quantified and characterized. Initially, work should center on the regulated and criteria trace elements rather than on all that may be present. For trace metals their form, oxidation state, and the material(s) with which they are complexed or chelated should be determined. In addition, the release of trace elements and metals during process upsets and accidental spills should be estimated.

Task 2. The rates and extent of trace metal sorption to bedded and suspended sediments need to be determined. This will be dependent on water and sediment characteristics such as: pH, dissolved oxygen, sediment size, organic content, etc.

Task 3. The availability of trace elements and metals to aquatic biota from water and/or sediments needs to be established. To do this, trace metal levels in water, sediments and biota downstream from coal conversion discharges should be measured. Baseline monitoring should start at least one year before plant construction.

Task 4. Transport models are available and are of value because of their predictive capabilities. However, since models tend to be developed for local/regional conditions, a trace metal transport model should be selected and adapted for application to at least one demonstration plant site. Model predictions can then be validated by using the results of the baseline monitoring program (Task 3).

3.7 Problem Statement: Aqueous Discharge of Inorganics

The transport and fate of inorganic effluent constituents, other than trace elements, released in direct aqueous discharges need to be determined. It is anticipated that NH_3, CN^-, and SCN^- will occur in treated product water. Transport processes will differ between the oxidizable forms of NH_3, CN^-, and SCN^- due to their different physical/chemical properties. Salts produced during pretreatment, blowdown and recycling operations may also be released. High concentrations of salts may precipitate downstream, thereby altering aquatic habitats. High levels of these and other possible inorganics will reduce water quality and may be toxic to aquatic organisms.

Quantification of inorganic contaminant levels in coal conversion effluents is not presently available; however, estimates exist on the levels of inorganics in effluents from coking and petroleum refining processes. There are substantial data on NH_3 and CN^- degradation in water, but less data are available on the degradation of SCN^-.

A variety of hydrological models is available which can be adapted to predict the movement of conservative salts and degradable inorganics when specific input data exist.

Task 1. The effectiveness of various treatment processes in removing CN^-, SCN^-, and NH_3 should be determined. The levels of salts and other major inorganics in treated effluent discharges need to be quantified both under normal operating and accident conditions.

Task 2. The environmental and chemical reactions of inorganic contaminants discharged in surface waters should be characterized. This should include measurements of the rates of volatilization, degradation, and oxidation of non-conservative species.

Task 3. In order to obtain complete background data on the plant region for subsequent use in transport models, hydrological patterns at coal conversion plant sites should be determined. Baseline monitoring of inorganics and salts should begin at least one year before plant construction. This could ideally be combined with baseline monitoring for trace metals and organics.

Task 4. Using data from Tasks 1-3, transport models should be adapted to predict the distribution of salts and inorganics downstream from the plant site. Post-operational monitoring data should be used to validate model predictions.

4.0 ECOLOGICAL EFFECTS

The opportunity to design and implement environmental research simultaneous to the development of new energy technologies bears with it the responsibility to assist the technology by alerting its designers to problems as they are identified. Thus, an objective of the ecological effects subpanel was to suggest research to reveal technology-related environmental problems which could be brought to the attention of coal gasification and liquefaction process engineers and control technologists in a timely manner. The anticipated results of a rapid information feedback loop would be altered designs and operations which could mitigate the environmental problems identified.

The need for identification of the form, source, and potential environmental concentrations of organic and inorganic contaminants was recognized by this subpanel as an extremely important objective of the workshop. Once potential contaminants have been identified, toxicological methodologies need to be implemented. There are a number of problems with implementing these test methods. A major concern is the large number of potentially hazardous contaminants that will be identified and the impossibility of conducting toxicity tests on all of them. Therefore, a prioritization of specific contaminants and classes or categories of contaminants should be established to determine which should be tested first.

Another concern is the need to prioritize the order in which different types of toxicological tools are to be implemented for evaluating the hazardous potential of contaminants or groups of contaminants. The array of toxicological tools currently available includes tests for mutagenicity, carcinogenicity, teratogenicity, and lethality; chronic and subchronic effects on reproduction, behavior, physiology, and bioaccumulation by trophic level (e.g., algae, invertebrates, fish); and community and ecosystem interactions. Compounds suspected to be carcinogenic probably will not require acute lethality testing; whereas, for an unknown contaminant, an entire battery of tests may be required.

Current toxicological tools are numerous and very few have been standardized. Standardization of test methodologies needs to be addressed if comparative toxicity data are to be obtained. Further, many toxicity tests are inadequate for predicting effects on aquatic biota and ecosystems in field situations. Current test methods need to be evaluated and modified, or new tests developed to increase our capability for predicting the effects of coal conversion contaminants upon aquatic ecosystems. A program for in situ biomonitoring should also be developed.

No attention has been specifically directed toward research for restoring or enhancing the recovery of impacted aquatic ecosystems, especially those impacted by episodic spills. Because episodic spills do occur, and will continue to occur, methodologies to speed the reestablishment of biota need to be investigated if aquatic ecosystems are to be preserved.

The effects of coal conversion contaminants on aquatic ecosystems may be manifested at all hierarchical levels of organization, from the suborganismal to the ecosystem level. Suborganismal effects include mutagenic and biochemical changes. Organismal effects include carcinogenicity, teratogenicity, lethality, sublethal changes in behavioral and physiological phenomena, and impairment of growth. Populations may exhibit reproductive impairment which could affect the structure and function of ecosystems, the ability of the ecosystem to assimilate waste materials, and to respond to short- and long-term exposure to contaminants.

4.1 Problem Statement: Chemical Characterization of Coal Conversion Contaminants

Natural receiving waters will be affected by liquid effluents, solid waste leachates, and atmospheric emissions which originate from coal conversion technologies. These contaminants represent a unique source and group of elements and compounds. An efficient and logical scheme should be developed to identify, categorize, and predict environmental concentration of principal organic and inorganic contaminants which may affect water resources. Particular categories of toxicants should be identified according to specific technologies, process conditions, sources of feeder coal, waste treatment procedures, and means of entry into aquatic ecosystems. The data will provide the initial basis on which to establish priorities for toxicological, ecological, and environmental fate studies.

Substantial data are available on inorganic contaminants occurring in coal effluents and emissions, but more adequate information should be developed on aqueous leaching of trace elements from different types of coal and solid waste residues. Information on organic compounds is far less complete, and data remain to be collected for all above categories. Most of the existing information is in the form of lists of likely contaminants. There is a particular need for comparative data on treated and untreated effluents and wastewaters. Identification of compounds from fractional distillates of coal tar has provided an indication of the large number and diverse nature of organics which may result from conversion, and some initial data exist on chemical fractionation of certain effluents (e.g., acid/base extraction of SRC process water). Although several principal classes of organics (e.g., aromatic hydrocarbons, phenols, thiophenes, aromatic amines) have been associated with coal conversion, detailed analytical and monitoring data are largely incomplete.

Task 1. All major liquors, waters, and condensates associated with coal conversion need to be chemically categorized. Results should provide an identification of principal subfractions (e.g., acid/base extracts, distillates) and their major constituents, including concentration data for trace elements and inorganic and organic compounds. Priority should be given to effluents and wastewaters routinely released to the environment, as well as to all process waters, liquors, and liquid products subject to accidental discharge from closed systems. Analytical data should be developed on the composition of untreated and treated effluents.

Task 2. The leaching potential of solids (e.g., feeder coal, fuel chars) and solid wastes (e.g., ash, char, slag, sludge) exposed to weathering need to be evaluated. Leaching rates for principal inorganic and organic contaminants should be determined. Laboratory models should be developed to simulate actual leaching conditions (e.g., landfill, ponding) and, where possible, laboratory results should be compared with surface and groundwater monitoring data.

Task 3. The principal elements and compounds contained in atmospheric emissions from coal conversion need to be determined. Fractional quantities which may enter water resources as a result of local deposition flux, terrestrial runoff, or general atmospheric scavenging should be estimated.

Task 4. Comparative environmental emission data for different conversion technologies and feeder coals need to be developed. Major process variables should be characterized according to environmental risk or acceptability.

Task 5. The efficiency of biodigester technology for removal of potentially deleterious elements and compounds needs to be determined. Particular attention should be given to chemical constituents which may be refractory to biodigestion. If biodigestion technology changes or is replaced by new pollutant control measures, similar research should be conducted prior to or concomitant with implementation of new procedures.

4.2 Problem Statement: Toxicological Screening of Coal Conversion Contaminants

Aquatic ecosystems will be affected by a broad spectrum of pollutants originating from liquefaction and gasification. Assessments will depend on the establishment of an orderly and systematic program for toxicological screening of coal-derived contaminants and groups of contaminants.

Over 60 inorganic elements occur in coal, and the majority of these have been detected at appreciable concentrations in process waters, wastewaters, or solid waste leachates associated with coal conversion. In addition, aquatic ecosystems potentially may be affected by hundreds of organic compounds, such as phenols, arylamines, aliphatic hydrocarbons, mono- and polycylic hydrocarbons, and thiophenes. Water quality criteria have not been established for the majority of coal-derived trace contaminants, but many are known to be highly toxic (e.g., biphenyls), teratogenic (e.g., boron, phenol), mutagenic (e.g., dimethylamine, hydroxylamine, β-mercaptoethanol), or carcinogenic (e.g., benzo(a)pyrene, benzidine, β-naphthylamine).

The vast number and diverse physical-chemical characteristics of coal conversion contaminants place some constraints on the extent of toxicological testing which can be accomplished within the time span contemplated for development and implementation of liquefaction and gasification technologies. Therefore, it is especially important to develop effective bioassay screening programs to identify those toxicants or groups of toxicants most likely to exert detrimental effects on aquatic biota. Initial toxicological investigations should focus on "key" contaminants or "representative" elements or compounds of important categories. Attempts should be made to correlate toxicity with compound-specific characteristics (e.g., molecular configuration, substitution groups) which may be of predictive value. Prudent application of predictive toxicology may minimize the economic burden of testing programs.

There is considerable need to improve current bioassay methodology. Many toxicity tests have been proposed, but the majority of these tests has been developed for pure compound studies with a single species maintained under simplified experimental conditions. Modification of test methodologies and development of new tests may be necessary to obtain more reliable and defensible data more rapidly so that the feedback of biological data to technological personnel occurs expediently. Tests using aquatic organisms should be developed for the detection of carcinogens, mutagens, and teratogens, since disproportionately high percentages of such compounds occur in coal wastes. Toxicological testing is further complicated by the fact that coal conversion contaminants occur as complex mixtures, with the potential for antagonistic, additive, or synergistic interactions. Since the toxicity of these mixtures is difficult to predict using conventional bioassays, on-line (in situ) biomonitoring systems should be designed to give direct toxicological information on complex effluents and receiving waters.

Results of toxicity screening will permit identification and quantification of toxic properties of important contaminants originating from coal conversion. Results will also contribute to: (1) the planning of other aspects of hazard assessment (e.g., ecological effects, environmental fate), (2) the development of water quality criteria for hazardous compounds, and (3) the formulation of guidelines for waste treatment and disposal.

Substantial data are available on the toxicity of heavy metals (e.g., Cd, Cu, Hg, Pb, Zn) to aquatic organisms. However, freshwater criteria are incomplete for many inorganics (e.g., Al, Ag, B, Cr, Fe, Ge, Ni, Sb, Bi, Ce, F, Li, Rb, Sr) which appear at detectable concentrations in coal conversion effluents, wastewaters, and leachates. In addition, aquatic toxicity data and freshwater criteria must be generated for the vast majority of organics which originate from coal conversion. Data gaps are particularly conspicuous for embryo-larval and chronic life-cycle studies. Though limited attempts have been made to identify mutagenic and carcinogenic compounds originating from coal technologies, virtually no test data exist for aquatic organisms. Teratogenic effects (i.e., birth defects) produced by coal contaminants also remain to be investigated. When available, such information will be applicable to a wide range of water quality and health-related considerations.

A few toxicological investigations have been conducted on coal ash leachates and coal conversion effluents, but additional work in this area is necessary. Encouraging preliminary information exists on the design and use of on-line toxicological monitoring systems. Pilot studies have been performed on untreated and treated coal effluents, and results indicate the potential of in situ biomonitoring systems for evaluating effectiveness of alternative waste treatment procedures. Initial studies have been conducted on chemical fractionation as a means of analyzing toxic components of complex effluents and the success of this approach warrants increased emphasis.

Task 1. New bioassay systems for rapid-scan analysis of contaminants originating from coal conversion need to be developed. The utility of currently recommended toxicity tests needs to be assessed. Effective bioassay procedures for testing insoluble and volatile compounds in aquatic systems which eliminate carrier solvents and minimize evaporative loss of toxicant need to be developed. The correlation of water quality parameters and toxicological responses needs to be determined. Investigations should focus on identification of opportune test species, reliable and economical methods, standardized bioassay conditions, and functional protocols.

Task 2. Bioassays on "key" or representative inorganic and organic contaminants for which adequate water quality criteria do not exist need to be performed. Priorities should be placed on screening substantial numbers of coal-derived contaminants before major efforts are devoted to time-consuming chronic bioassays. Inorganic elements for toxicological screening might include: Al, Ag, B, Ba, Be, Cs, Ga, Ge, Mg, Ni, Ta, Te, Ti, V, and Zr. Representative organic compounds selected from major chemical categories characterized in coal conversion wastes, and particular compounds judged important on the basis of high effluent concentration or high potential for biological effects, might include phenols, arylamines, aliphatic hydrocarbons, mono- and polycyclic hydrocarbons, and thiophenes.

Bioassay test procedures should include both acute and chronic screening tests with several important groups of aquatic organisms (algae, invertebrates, and fish). Dose-response data should be developed for sensitive life stages (e.g., eggs, embryos, larvae). Attention should be given to important sublethal effects (e.g., growth inhibition, bioconcentration) and to reproductive impairments.

Task 3. In situ biomonitoring procedures for direct toxicological measurements on complex effluents and receiving waters need to be developed. Priority should be given to flow-through systems, using sensitive test organisms (e.g., fish embryo-larval and juvenile stages) and short response time.

In situ toxicological measurements should be performed on effluents, solid waste leachates, and receiving waters. Results should provide quantitative information on full suites of coal-derived contaminants, including dilution ratios necessary to preclude short-term biological effects (e.g., mortality, teratogenesis, avoidance).

In situ biomonitoring should be applied to untreated and treated effluents or effluent fractions to compare toxic properties and evaluate waste treatment procedures.

4.3 Problem Statement: Prediction of Ecological Effects

Localized environmental impacts may result from construction and operation of coal conversion facilities. Assuming that the site has not been investigated previously, a thorough and comprehensive study program is required. As a minimum, data must be gathered on hydrology, water quality, and species inventory. This type of information will provide a basis for establishing pre-operational environmental quality and the degree of impact which might accrue from construction and operation of coal conversion plants.

Predictions of the impacts of contaminants on aquatic ecosystems currently are based on the results of many types of toxicity tests. The results of most of these toxicity tests do not correlate with field assessments, implying that the test methodologies are not truly predictive. Alterations in water quality parameters and interactions with sediments and biota are known to have significant effects on the toxicity of some materials. Such toxicity modifiers are rarely considered in toxicity tests. Further, most toxicity tests do not investigate the interaction of time-dose effects and the responses of aquatic communities to these effects.

Methods must be developed, therefore, to facilitate predictions of the effects of coal-derived contaminants on water quality, aquatic organisms, and entire aquatic ecosystems. Adequate predictions will require information on: (1) the influence of water quality on contaminant effects, (2) the influence of contaminant concentration and duration of exposure, (3) the variation in sensitivity between species and as a function of life stage, nutritional history, etc., and (4) the interactions between organisms coexisting in an aquatic ecosystem.

Published data demonstrating correlation between toxicity tests and field studies are limited. Research on Kepone and PCB's are exemplary of the problem. Unfortunately, most of these studies are on pure compounds or classes of compounds, and not on complex effluents.

The majority of published data on the effects of effluents on aquatic communities is based on comparisons of upstream to downstream sampling of biological and chemical parameters. If baseline data (i.e., preoperational) are lacking, the magnitude of the alleged impact may not be adequately documented. Existing data on the effects of episodic spills, which involve large slugs of wastes entering the aquatic ecosystem over relatively short periods of time, are "after-the-fact." For most episodic spills, community recovery data are lacking. Intermediate time-dose exposures (between episodic spills and long-term, low-level toxicant exposure) have rarely been studied. Studies have been limited to research evaluating the recovery and resistance patterns of protozoan microcosms and salt marsh communities to simulated oil spills or acid mine drainage.

Task 1. A water quality and hydrological characteristics data base for the surface waters potentially affected by a coal conversion facility needs to be developed. Information should be collected on seasonal flows, thermal regimes, flooding, sediment transport and deposition, dissolved oxygen, pH, total dissolved solids, total organic carbon, biological and chemical oxygen demand, etc.

An intensive field program designed to provide information including: species present, seasonal abundance, reproductive season and requirements, feeding habits, habitat requirements, etc. needs to be conducted. The study should address all major components of the ecosystem and include information on species interactions.

Task 2. The qualitative and quantitative effects of coal-derived contaminants on water quality parameters (e.g., total dissolved solids, total organic carbon, pH, biological and chemical oxygen demand, alkalinity, hardness) need to be identified. The effects of altered water quality parameters on the toxicity of coal conversion contaminants should be determined.

Task 3. The toxic effects which might actually occur in aquatic organisms under natural conditions need to be determined. Consideration should be given to: (1) effects of ecological variables (e.g., water quality, temperature, food supply) on toxicity, and (2) interactions between organisms (e.g., competition, predation, commensalism) which might modify responses to toxicants. Effects of contaminants on behavior, reproduction, and development should be included. Attempts should be made to relate the results of laboratory studies to organisms in their natural environment.

Task 4. The utility of available toxicity and microcosm test methodologies for predicting the responses of aquatic ecosystems to complex wastes and products needs to be assessed. It may be necessary to modify existing tests or develop new tests to increase their predictive capabilities.

Microcosm and/or field studies need to be conducted to determine the capacity of aquatic ecosystems to assimilate waste materials. This project should include an evaluation of transport models, contaminant sinks, and interactions of environmental parameters on contaminant materials to determine the rates at which wastes are assimilated.

The effects of long-term exposure of aquatic communities and ecosystems to complex coal conversion contaminants need to be assessed using both laboratory microcosm and field studies. The ability of aquatic communities to respond to relatively short-term, time-dose dependent episodic spills of coal conversion effluents and products needs to be determined. The response patterns of aquatic communities to these stresses should be characterized.

5.0 RANKING OF PROBLEM AREAS

Priorities were not developed for the problem areas described by the water quantity subpanel. All of the ecological effects problem areas were considered as high priority issues.

The transport and fate subpanel identified the following problem areas as major concerns in terms of aquatic transport and fate of contaminants released from coal conversion facilities. The listing can be considered to be ranked with regard to the urgency with which research in these areas should be undertaken.

Problem Statement	Priority
3.1 Leaching of contaminants from landfill disposal areas	High
3.2 Aqueous discharge of organics	High
3.3 Emissions from combustion of liquefaction products	Medium
3.4 Accidental spills of liquefaction products	Medium
3.5 Airborne release of contaminants	Medium
3.6 Aqueous discharge of trace elements	Low
3.7 Aqueous discharge of inorganics	Low

In establishing these priorities, the following points were considered:

- Possible extent of adverse effects to living organisms;
- The lack of scientific knowledge concerning the potential toxicity, mutagenicity, and fate of leachate from landfill disposal areas; and

- Adverse environmental effects resulting from increased industrial use of coal-derived products when a full-scale coal conversion industry exists.

Needed Research on the Terrestrial Effects of Coal Gasification and Liquefaction Technologies

A Report to the Federal Interagency Committee on the Health and Environmental Effects of Energy Technologies
Executive Secretariat/The MITRE Corporation
from the Terrestrial Effects Panel of the Workshop on Health and Environmental Effects of Coal Gasification and Liquefaction Technologies

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ABSTRACT

The Terrestrial Effects panel discussed the needed direction and techniques for future research in the terrestrial effects of new coal conversion technologies. Panel members concurred on the need for changes in emphasis, approach, and even attitude in environmental research. The following are the basic perceptions of the panel:

- Our goal is to provide for environmentally amenable technologies in coal conversion and product distribution, especially focusing on pollutants entering pathways to man. Highest research priority, therefore, should be given to solid wastes, and especially their leachates.

- A shift in research emphasis is needed. Whereas we have been accustomed to investigating acute effects of pollutants immediately surrounding their source, we should now explore the sublethal, long-term effects of pollutants carried farther from their source. These may in fact become the more dangerous of the two through bioconcentration. Research of this kind sould help us to predict deleterious effects before they are felt.

- Another needed reverse in typical environmental research strategy is to perform biological characterization before source characterization. To do this, we ask if there is an effect and find the answer by biological screening. If an effect is found, then the cause may be traced by source characterization.

- Time for the needed research is running out. In order to make meaningful progress within a short time frame, we will have to narrow the focus of our research to include only the most serious effects and only their most likely causes. To investigate these, just a few best alternative modes of operation could be selected and then constructed on a full commercial scale.

- Perhaps more than ever before, cooperation between disciplines is essential. Ecologists, biologists, engineers and statisticians must pool their knowledge and ideas in solving these problems. The panel was encouraged by the success of their own cross-disciplinary efforts as reflected in this summary.

FOREWORD

In spite of potential dangers to internal security, the United States grows increasingly dependent upon foreign oil to fuel its economy. Reducing this dependency through conversion of our own coal reserves to synthetic fuels has become a national priority. In so doing we must be certain that we do not create undue environmental and health risks. Recognizing this, the President has directed the Department of Energy, the Department of Health, Education and Welfare, and the Environmental Protection Agency to institute a detailed joint program to review the health and environmental problems associated with advanced energy technologies and the adequacy of the present environmental research program.

In response to this directive the three agencies sponsored a workshop on the Health and Environmental Effects of Coal Gasification and Liquefaction Technologies. This report summarizes the deliberation of the Terrestrial Effects panel. Its purpose is to prioritize specific problems for terrestrial ecosystems posed by development and commercialization, identify the information needed to solve them, and summarize the research needed to provide that information not currently available.

OVERVIEW

INTRODUCTION

It is important to keep in mind that most potential terrestrial problems for any technology currently under development are not known. Thus we are seeing the development of data bases that are largely new. Given the overwhelming array of technology options, process alternatives, feed coals, process/waste streams and pathways for environmental effects, we must be very judicious in our allocation of men and material to environmental research if we are to provide the basis for sound decision-making within reasonable limits of time and cost. (Decision-making, as used in this report, is the selection by technology developers and environmental protection institutions of coal conversion technologies and the legal, political and social restraints under which they operate.) This demands a holistic approach, systematically organizing a comprehensive statement of problems and strategies for their solution according to a national scheme of priorities.

PANEL DECISIONS ON RESEARCH PRIORITIES

Working from these premises, the panel looked at the whole fuel cycle (Figure 1). We concluded that problems of extraction and transport of coal are fairly similar across all technologies and have already received considerable attention. Problems of end-use, however, are of great importance (especially as they affect market penetration), but too little is known of plans for end-user facilities to permit sound research recommendations at this time. Therefore, we focused on problems of coal conversion and product distribution as being of highest current priority.

As shown in Figure 1, the two principal vectors for the movement of pollutants from industrial sources to terrestrial receptors are air and water. Assuming that the greatest research efforts should be directed at pollutants which are "unique" to the technology of concern, air emissions of criteria pollutants were not given high priority. However, certain noncriteria pollutants, about which little is known but for which there is a basis for environmental concern (such as carbonyl sulfide, COS, and organics in cooling tower drift, mercaptans as air pollutants, amines and quinolines in aqueous discharges and solid waste leachates), should receive careful attention. Similarly, lower emphasis was given materials dissolved or entrained in surface waters because, except for drinking and crop irrigation, this is not a principal route by which deleterious levels of pollutants would be transported to vegetation and animals living on land. On the other hand, all proposed coal gasification and liquefaction technologies will produce large masses of solid materials to be disposed (or in the case of *in situ* gasification, left) under large acreages of the soil surface. Very little is known about the potential effects of these materials, particularly from expected burdens of complex organic materials. Thus the fate and effects of solid wastes, and particularly their leachates, should receive the highest priority in terrestrial effects research.

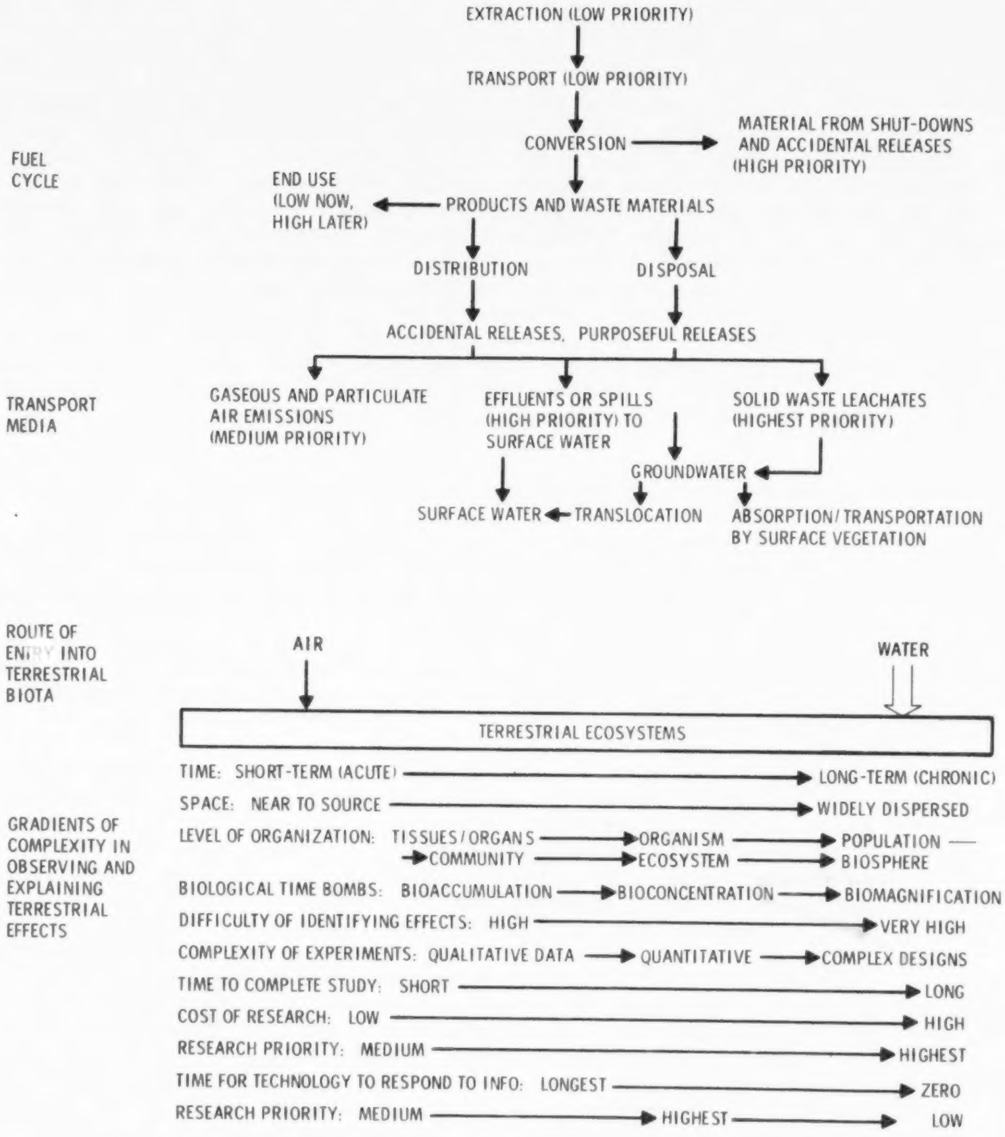
EXTRACTION (LOW PRIORITY)
TRANSPORT (LOW PRIORITY)
CONVERSION
MATERIAL FROM SHUT-DOWNS AND ACCIDENTAL RELEASES (HIGH PRIORITY)
FUEL CYCLE
END USE (LOW NOW, HIGH LATER)
PRODUCTS AND WASTE MATERIALS
DISTRIBUTION
DISPOSAL
ACCIDENTAL RELEASES, PURPOSEFUL RELEASES
TRANSPORT MEDIA
GASEOUS AND PARTICULATE AIR EMISSIONS (MEDIUM PRIORITY)
EFFLUENTS OR SPILLS (HIGH PRIORITY) TO SURFACE WATER
SOLID WASTE LEACHATES (HIGHEST PRIORITY)
GROUNDWATER
SURFACE WATER
TRANSLOCATION
ABSORPTION/TRANSPORTATION BY SURFACE VEGETATION
ROUTE OF ENTRY INTO TERRESTRIAL BIOTA
AIR
WATER
TERRESTRIAL ECOSYSTEMS
GRADIENTS OF COMPLEXITY IN OBSERVING AND EXPLAINING TERRESTRIAL EFFECTS
TIME: SHORT-TERM (ACUTE) → LONG-TERM (CHRONIC)
SPACE: NEAR TO SOURCE → WIDELY DISPERSED
LEVEL OF ORGANIZATION: TISSUES/ORGANS → ORGANISM → POPULATION → COMMUNITY → ECOSYSTEM → BIOSPHERE
BIOLOGICAL TIME BOMBS: BIOACCUMULATION → BIOCONCENTRATION → BIOMAGNIFICATION
DIFFICULTY OF IDENTIFYING EFFECTS: HIGH → VERY HIGH
COMPLEXITY OF EXPERIMENTS: QUALITATIVE DATA → QUANTITATIVE → COMPLEX DESIGNS
TIME TO COMPLETE STUDY: SHORT → LONG
COST OF RESEARCH: LOW → HIGH
RESEARCH PRIORITY: MEDIUM → HIGHEST
TIME FOR TECHNOLOGY TO RESPOND TO INFO: LONGEST → ZERO
RESEARCH PRIORITY: MEDIUM → HIGHEST → LOW

FIGURE 1. Technological and Ecological Considerations Influencing the Selection of an Environmental Research Strategy

THE TERRESTRIAL BIOLOGIST'S ROLE

If we accept that dependence upon foreign oil must be reduced through conversion of our own coal resources, then our goal as environmental scientists is to facilitate the development of environmentally amenable coal conversion technologies. A major problem in achieving this goal has its origin in the history of environmental research and the resulting state of the art. Most environmental research to date has concentrated on short term effects occurring near the source of pollutants where concentrations are highest (Figure 1). As a general rule the specific chemicals causing the observed toxicity are likely to be the more soluble compounds that are easily incorporated into living tissues. Because of increased dilution and rapid turnover rates, these effects are reduced as one moves away from the point of discharge. Historically, control technology in such cases has often become the simple expedient of increased dilution at the point of discharge.

Of even greater concern now, requiring more attention, are the less soluble pollutants which are not as readily incorporated into living tissue. Once there, however, they may tend to accumulate, often concentrating in specific tissues and organs. Such materials have the potential for biomagnification through living food chains. Even when released at very low concentrations they may be "biological time bombs" having the potential for later damage at far greater distances from the point of release than is the case for acutely toxic substances. Prediction and prevention of these effects from such materials may be far more difficult since minute quantities released over long periods of time may be disproportionately harmful.

As we deal with these problems we must also deal with problems of instrument detection limits and increasingly complex experimental designs, relying more and more upon statistical decision-making. In pursuing this course we can anticipate increasing restraints on time for completing our studies and on funds for materials and manpower. Concurrently the time available for a technological adjustment to environmental research results is approaching zero. When this happens our role changes from "facilitating environmentally amenable technology development" to an academic exercise. Consequently, research designs must be balanced to yield the best possible answers within a time frame that allows their maximum utilization in the decision-making process.

Within these constraints, the terrestrial panel strongly recommends that the focus of environmental research be shifted from acute effects to sublethal and long-term or chronic effects, especially at the ecosystem level and particularly where the anticipated chain of events could be traced to man. Problems at this level are so complex that considerable attention must be given to identifying the key parameters and processes of selected ecosystems as perturbed by industrial pollutants and then developing predictive models of their interaction. The testing of these predictions through long-term monitoring of both laboratory and field conditions is the necessary vehicle for adding to our information base and, thereby, for improving our predictive capabilities. The ultimate goal of environmental research should be to develop a capability for predicting detrimental effects before they occur, thus enabling us to take steps to avoid them in the first place by engineering design or application of control technology.

Several concerns were raised by panel members which relate to the above, but deserve specific mention on their own merit. These include a caution against the continuing but dangerous trend to evaluate new industrial projects singly, allowing regional problems to creep up on us by insidious increments. Further, we must guard against adopting a false sense of security just because pollutant concentrations are expected to be low. The potential for bioaccummulation and the ability of some substances, like polycyclic aromatic hydrocarbons (PAH's), to act as hormones at almost undetectable levels bears consideration in environmental research design. Finally, in baseline definition and long-term monitoring programs it is imperative to remember that year-to-year parametric variation may be extreme. Thus, there is not only a baseline mean but a baseline variance to be established for each biological parameter to be monitored.

NEED FOR INTERDISCIPLINARY APPROACH

Another perception of the terrestrial panel is that our environmental, and even our terrestrial, problems cannot be resolved by terrestrial ecologists alone. Instead, a great deal of information will have to be exchanged across traditional disciplinary and institutional boundaries. In many cases, where tradition and "territorial" interests impede this free exchange, some "forcing functions" will have to be provided. Figure 2 shows the principal interactions required to provide decision-makers with results of relevant terrestrial effects research.

Information exchange between ecological and source characterization scientists is crucial, because they each characterize developing technologies differently. The latter describes the technology in terms of the physical and chemical properties of the materials it produces, and the former describes it in terms of the environmental effects of these materials. In order to understand how source materials may bring about environmental effects we must have detailed knowledge of both. Traditionally this has been approached first by source characterization, to see if there were any potentially toxic agents in the material, and then by biological characterization to gauge the seriousness of the anticipated response. For at least two reasons this is not the choice research strategy for newly developing technologies. First, the state of the art for chemical source characterization is largely inadequate. Considerable development in methodology is required before meaningful work can proceed. Second, even if such methodology were available we could not afford to analyze all relevant combinations and permutations of potentially toxic process streams. Moreover, even if we did, current knowledge of biological effects of each chemical species contained in the extremely complex process streams would not allow us to predict effects simply on the basis of their expected real-world concentrations.

Alternatively, a "top-down" strategy which begins with biological characterization is recommended. We first ask the question "Is there a potential

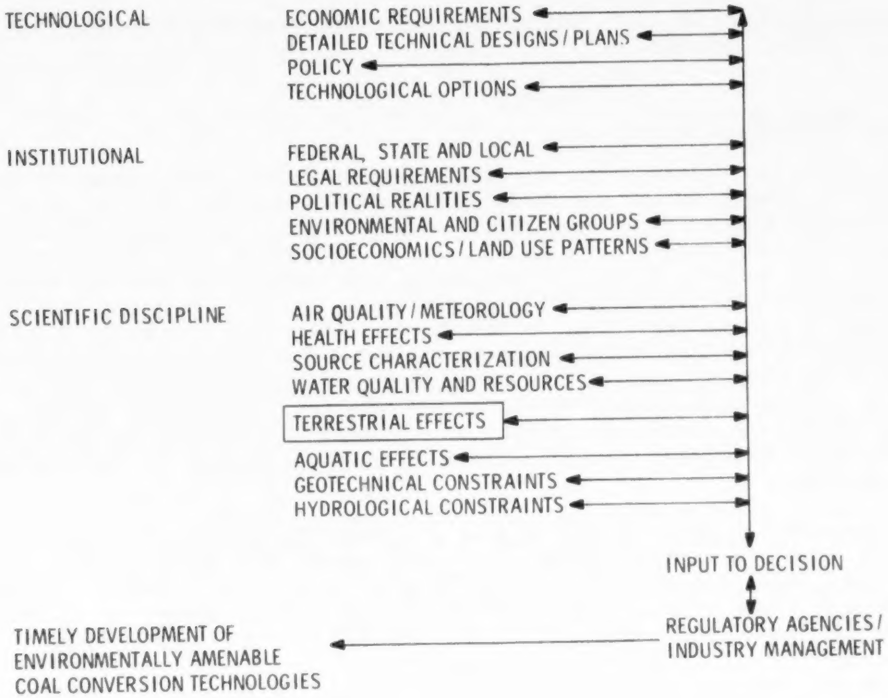
TECHNOLOGICAL
ECONOMIC REQUIREMENTS
DETAILED TECHNICAL DESIGNS / PLANS
POLICY
TECHNOLOGICAL OPTIONS
INSTITUTIONAL
FEDERAL, STATE AND LOCAL
LEGAL REQUIREMENTS
POLITICAL REALITIES
ENVIRONMENTAL AND CITIZEN GROUPS
SOCIOECONOMICS / LAND USE PATTERNS
SCIENTIFIC DISCIPLINE
AIR QUALITY / METEOROLOGY
HEALTH EFFECTS
SOURCE CHARACTERIZATION
WATER QUALITY AND RESOURCES
TERRESTRIAL EFFECTS
AQUATIC EFFECTS
GEOTECHNICAL CONSTRAINTS
HYDROLOGICAL CONSTRAINTS
INPUT TO DECISION
REGULATORY AGENCIES / INDUSTRY MANAGEMENT
TIMELY DEVELOPMENT OF ENVIRONMENTALLY AMENABLE COAL CONVERSION TECHNOLOGIES

FIGURE 2. Information Exchanges Required to Provide Results of Relevant Terrestrial Effects Research to Decision-makers

biological effect?" and answer that question through some sort of biological screening of the whole source term material, e.g., microcosm screening. If an effect is observed, and if it is judged "significant" in the sense that it could occur in a real-world environment associated with a demonstration-sized (or larger) facility, then we may have to pursue the specific cause more closely by identifying the stream origin, then perhaps the chemical fraction, and finally (in instances where control technology can be applied only when the process engineer knows the exact cause of the problem) the chemical species and the causative mechanism by which it brings about the effect. This approach allows us to evaluate at each step the need to go farther relative to the information value of other ongoing investigations. Faced with the impossibility of looking at everything, we must play the odds carefully by attacking our problems in steps, focusing at each step on the most likely avenues for only the most serious effects. Viewed positively, this gives us the greatest chance of flagging and later predicting the most serious effects. Viewed negatively, by leaving many avenues unexplored we proceed at some risk of missing something significant. However, if we do not adopt this strategy of selective risk-taking we could become so hopelessly bogged down as to take the greatest risk of all: coal conversion might proceed but without needed environmental controls.

THE PROBLEM OF SCALE

During our interactions with the source characterization panel it became clear that there are in some cases insurmountable problems in scaling up our predictions from existing bench scale models, Process Development Units or pilot plants to demonstration and commercial facilities that are yet to be built. For example, it may not be possible to address the problems created by air emissions, particularly fugitive emissions, or the effectiveness of liquid effluent treatment facilities (either because there are none built or existing ones are not representative) prior to the demonstration phase. The uncertainties of scaling up, coupled with uncertainties inherent in biological variations, will in many cases relegate needed research to a "futile" category. As a result, the terrestrial panel feels obliged to recommend action that others will agree with but will consider impossible because of institutional constraints.

We strongly advise that, instead of attempting to take all viable processes through all stages of development (a course that requires more time and resources than we have) the most promising alternative be selected now for one or more of the most promising gasification/liquefaction technologies, and that it be developed at a commercial scale. Because of the financial risks (and the self-interests) involved, this would have to be entirely government-funded and managed. Such a facility should be built on a large enough area to permit construction of modules representing major process alternatives during operation. The whole design and purpose of the facility would be to conduct both technological and environmental research in a coordinated and interdependent manner.

There are admittedly serious legal and institutional barriers to such a course of action. We recommend the construction of a facility that would probably be an uneconomical, "dirty" plant. Then intensive research on how best to make them run both cleanly and economically could be performed at a more realistic level. The potential benefits more than justify the efforts expended in removing the barriers. By conducting our experiments at the expected scale of development we could be most sure of the correctness of our answers. Focusing our resources on relatively few alternatives would increase chances of answering all the important questions, even the long-term ones, and in the shortest possible time frame.

Before this interdisciplinary approach is discounted we would like to comment on a remarkable event that occurred within our panel and perhaps other panels. It might be termed a "cross-disciplinary challenge and its synergistic response." We believe it has to do with the unique character of the problem we are addressing. It is almost as if, while working hard at their respective benches, scientists heard the President's request and simultaneously perceived that this thing is important and feasible, but that it will require the best that all of us can cooperatively bring to bear on the problem to arrive at solutions. Thus there was a remarkable lack of territorial guardedness and a good deal of enthusiastic cooperation in panel interactions. Perhaps what we are seeing, both in the synergism of scientists from the field and in the cooperation of the three agencies from the federal level, is fueled by a common sense of urgency about the need to deal effectively with a crisis that is far more threatening to our way of life than sputnik ever was. If, as a result of that challenge, we could put a man on the moon, can we not as a nation set aside the "barriers" and meet this present challenge even more impressively?

The Terrestrial Effects panel believes we are dealing here with a different breed of problems requiring more information exchange than any problem set we have dealt with heretofore. We believe that workshops of the kind whose result is summarized here play a unique role in breaking down institutional and disciplinary barriers to such exchange. We left the workshop with the fervent intent of implementing some of our new perceptions in our own institutions and in our own disciplines. As a final recommendation, we suggest that there be an opportunity to meet again, perhaps in about a year and a half, to share the results of those efforts and to apply the experience gained to a more focused plan of attack. We would expect significant progress to result.

PANEL METHODS FOR IDENTIFYING APPROPRIATE RESEARCH

The problems with which we are dealing are so complex that a systematic approach to their definition is a prerequisite to their solution. The Terrestrial Effects panel systematically defined problem areas and guidelines for prioritization before proceeding to deal with the problems themselves. Because the "systematic approach" which evolved incorporates the assumptions upon which resulting problem definitions depend, both are provided herein.

SYSTEMATIC APPROACH TO PROBLEM DEFINITION

As a first step the panel identified five major process activities--extraction, transport, conversion, distribution and end use--and ranked them according to research priorities shown in Figure 1. Then a series of tables was prepared to assure consideration of the total range of interactions between technology development and the biological environment (Tables 1 through 4). Each table deals with a single medium category (air, water, land, other) into which source materials might be introduced, and breaks down the five major activities into 24 subactivities or process steps (Antizzo 1978, page 109). These are listed across the top of the table. The left column of each table lists the source materials which could be introduced into the medium of concern by any of the 24 subactivities. These source materials are listed according to the phase they are in when introduced and may be regarded as potential "agents" causing environmental effects (perturbations). In the body of the table the technologies (liquefaction, surface gasification or *in situ* gasification) are identified from the environmental effects which may be anticipated for the given agent under the given subactivity. Thus, all known, expected or potential change agents are identified for all technologies under all process activities for every medium into which change agents might be introduced.

The next step was to develop a preliminary list of potential environmental "receptors" which might usefully be monitored for responses to change agents (see page 16). Generation of such a list and selection of attributes to be measured from it is crucial in the design of a given research program. Important criteria to apply in this process include:

- Existing knowledge about the attribute
- Importance of the attribute in regulating flows of material or energy between ecosystem components
- Legal or socioeconomic importance of the attribute
- Ease of experimental handling and measurement of the attribute
- Likelihood of measurable response to the industrial change agents in question
- Necessity for including abiotic factors and representing all levels of biological organization in research program design.

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TABLE 1. Possible Change Agents Introduced into the Air by Each Technology Under Each Subactivity or Process Step

	Subactivities																								
Change Agents From Source Materials	Coal Storage	Coal Crushing	Coal Drying	Partial Oxidation	Briquetting	Coal Gasification	Gas Quench	Acid Gas Removal	Water Gas Shift	Methanation	Waste Water Treatment	Air Pollution Control	Solid Waste Control	Utility Power Production	Cooling Towers	Auxiliary Processes	Slurry Preparation	Pyrolysis/Hydrocarbon.	Hydrogenation	Hydrotreating	Phase Separation	Fractionation	Pregasification	Gasification In Situ	Phase of Agent Introduced
SO$_x$						2	2,3	2,3			2,3	2,3	2,3	1-3		1-3		1	1	1	1	1	3	3	Gas
NO$_x$						2	2,3	2,3			2,3	2,3	2,3	1-3		1-3		1	1	1	1	1	3	3	
CO						2	2,3	2,3						1-3		1-3			1		1			3	
CO$_2$						2	2,3	2,3						1-3		1-3						1		3	
Sulfur Compounds (H$_2$S, COS, CS$_2$, Thiols)						2		2,3			1-3	1-3	1-3	1-3	1-3	1-3		1			1				
Nitrogen Compounds HCN, NH$_3$						2		2,3		1-3	1-3	1-3	1-3	1-3	1-3	1-3		1	1	1	1			3	
Volatile Organics			1,2	1,2	1,2	2		2,3				1-3	1-3	1-3	1-3	1-3	1	1	1	1	1			3	
Other Noncondensibles													1-3												
Volatile Trace Elements						2				2,3	1-3	1-3		1-3	1-3									3	
Metal Carbonyl										2,3															Liquid
Phenols						2									1-3										
Water Vapor																								3	
BTX				1,2		2	2,3	2,3			1-3	1-3	1-3							1	1	1			
Oil Aerosol						2																			
Sulfuric Acid Mist															1-3	1-3									
Tars						2																			
Fumes						2												1	1				3	3	
Particulates	1,2	1,2,3	1,2	1,2	1,2		2,3					1-3				1-3		1		1	1	1		3	Solid
Coal Dust	1,2	1,2	1,2	1,2																					

Key: 1 - Liquefaction
2 - Gasification
3 - Gasification In Situ

TABLE 2. Possible Change Agents Introduced into the Land by Each Technology Under Each Subactivity or Process Step

Change Agents From Source Materials	Subactivities Coal Storage	Coal Crushing	Coal Drying	Partial Oxidation	Briquetting	Coal Gasification	Gas Quench	Acid Gas Removal	Water Gas Shift	Methanation	Waste Water Treatment	Air Pollution Control	Solid Waste Control	Utility Power Production	Cooling Towers	Auxiliary Processes	Slurry Preparation	Pyrolosis/Hydrocarbonat.	Hydrogenation	Hydrotreating	Phase Separation	Fractionation	Pregasification	Gasification In Situ	Phase of Introduced Agent
Soluble Gases																								3	Gas
Organics		1,2				2	2,3	2,3			1-3	1-3	1-3			1-3		1			1	1			
Solvents							2,3	2,3			1-3	1-3	1-3					1			1	1	3	3	
Contaminated Water	1,2	1,2				2	2,3	2,3			1-3	1-3	1-3		1-3	1-3								3	Liquid
Ash Slurry						2					1-3	1-3	1-3			1-3									
Sludge						2	2,3				1-3	1-3	1-3		1-3	1-3		1			1				
Oils & Tars						2					1-3	1-3	1-3			1-3		1	1	1	1	1	3	3	
Trace Elements	1,2	1,2				2	2,3	2,3			1-3	1-3	1-3	1-3	1-3	1-3		1	1	1	1	1	3	3	
Spent Catalyst										2,3		2,3							1						Solid
Ash/Slag		1,2				2	2,3					1-3	1-3	1-3		1-3		1			1	1		3	
Filter Cake								2,3					1-3												
Dust	1,2	1,2	1,2		1,2								1-3	1-3											
Fines		1,2	1,2		1,2																				

Key: 1 - Liquefaction
2 - Gasification
3 - Gasification In Situ

TABLE 3. Possible Change Agents Introduced into the Water by Each Technology Under Each Subactivity or Process Step

Change Agents From Source Materials	Subactivities																							Phase of Introduced Agent
	Coal Storage	Coal Crushing	Coal Drying	Partial Oxidation	Briquetting	Coal Gasification	Gas Quench	Acid Gas Removal	Water Gas Shift	Methanation	Waste Water Treatment	Air Pollution Control	Solid Waste Control	Utility Power Product.	Cooling Towers	Auxiliary Processes	Slurry Preparation	Pyroloysis/Hydrocarbon.	Hydrotreating	Phase Separation	Fractionation	Pregasification	Gasification In Situ	
Acid Gases (H_2S, CO_2, COS, SO_x)							2,3	2,3	2,3		2,3		2,3	2,3	2,3								3	Gas
Ammonia																		1	1					
Phenols							2,3						2,3											
Dissolved Salts							2,3				2,3	1-3	2,3											
Soluble Organics	1,2	1,2			1,2		2,3				2,3	1-3	2,3											
Soluble Ash	1,2	1,2			1,2		2,3				2,3	1-3	2,3											Liquid
Trace Elements	1,2	1,2						2,3				1-3	2,3										3	
BTX							2,3				2,3												3	
POM		1,2	1,2	1,2	1,2		2,3				2,3	2,3	2,3	2,3			1		1	1	1	3	3	
Tars & Oils							2,3	2,3			1-3		1-3			1-3				1				
Suspended Solids	1,2	1,2					2,3	2,3			1-3	1-3	1-3		1-3	1-3				1	1	3	3	
Runoff/Leachate	1,2	1,2											1-3									3	3	Solid
Sour Water/Brine							2,3	2,3	2,3															
BOD	1,2										1-3		1-3											
COD	1,2						2,3				1-3		1-3											

Key:
1 - Liquefaction
2 - Gasification
3 - Gasification In Situ

TABLE 4. Possible Change Agents Introduced Through Media Other Than Air, Land or Water by Each Technology Under Each Subactivity or Process Step.

Change Agents	Subactivities Coal Storage	Coal Crushing	Coal Drying	Partial Oxidation	Briquetting	Coal Gasification	Gas Quench	Acid Gas Removal	Water Gas Shift	Methanation	Waste Water Treatment	Air Pollution Control	Solid Waste Control	Utility Power Production	Cooling Towers	Auxiliary Processes	Slurry Preparation	Pyrolosis/Hydrocarbon.	Hydrogeneration	Hydrotreating	Phase Separation	Fractionation	Pregasification	Gasification In Situ	Support Systems
Noise	1,2	1,2			1,2	2						1-3	1-3												1-3
Thermal			1,2	1,2			2,3							1-3	1-3									3	
Land Use	1,2												1-3		1-3									3	1-3
Esthetics	1,2	1,2				2							1-3		1-3				1						1-3
Socioeconomics						2													1					3	1-3
Spontaneous Combustion	1,2								2															3	
Subsidence															1-3*									3	

Key: 1 - Liquefaction
2 - Gasification
3 - Gasification In Situ

*Water drawdown

Preliminary List of Environmental Receptors Which May Be Usefully Monitored for Responses to Change Agents

I. Abiotic

- Precipitation
- Snow melt/infiltration
- Evaporation
- Interlayer infiltration
- Percolation
- Radiation
- Reradiation
- Convection
- Humidity
- Springflow
- Streamflow
- Groundwater

II. Cells and Tissues of Accumulation

- Somatic
- Reproductive

III. Organismic Processes

- Transpiration
- Photosynthesis
- Respiration
- Translocation
- Shoot death
- Root death
- Shattering
- Decomposition
- Excretion
- Efficiency
- Growth
- Longevity
- Disease resistance

IV. Population Processes

- Immigration
- Emigration
- Natality
- Mortality
- Abundance
- Biomass

V. Community Characteristics

- Diversity
- Dominance

VI. Ecosystem Characteristics

- Litter/detritus decomposition
- Production
- Production/respiration
- Water cycle
- Nutrient cycle
- Food chain complexity
- Resiliency
- Resistance

TABLE 5. Change Agents of Concern to Terrestrial Environment and Potential Receptors at Several Levels of Environmental Organization Where Air or Land is the Medium of Introduction

	Receptors						
Agent	Abiotic	Accumulation	Organism Process	Population	Community	Ecosystem	Comments
AIR MEDIUM							
SO_x	Precipitation	Leaves	Physiological	Biomass	Diversity	Nutrient retention	
NO_x	Temperature	Leaves	Physiological	Biomass	Diversity	Nutrient retention	
CO	Humidity						Concentrations low
CO_2	Background concentrations						Concentrations low
Sulfur Compounds		Soil exchange sites	Growth reproduction	Abundance	Diversity	Nutrient cycle	Regional impact
Nitrogen Compounds							Concentrations low
Volatile Organics							Research needed
Other Non-condensibles		SE-Leaves		SE-Abundance			Low priority for research
Volatile Trace Elements		Leaves				Food chain	
Metal Carbonyl							Need source information
Phenols							Controls effective?
Water Vapor (in solution evaporation)			Physiological	Biomass	Dominance	Production	Not sure significant
BTX							Research needed? Output quantity?
Oil Aerosol							Research needed? Output quantity?
Sulfuric Acid Mist		Leaves	Physiological	Biomass		Production/ nutrient cycle	
Tars							Concentrations low. Output quantity?
Fumes							Covered elsewhere
Particulates		Leaves, lungs	Physiological, respiratory	Abundance/ biomass	Dominance	Production/ nutrient cycle	Quantity?
Coal Dust		Leaves, lungs	Physiological, respiratory	Abundance/ biomass			Localized
LAND MEDIUM							
Soluble Gases	Groundwater quality						
Organics	Water quality	Soil matrix	Microbial, roots, invertebrates, fossorial	Biomass		Decomposition Nutrient cycle Bioconcentration	Practically nothing known
Solvents							
Contaminated Water							
Ash Slurry							
Sludge							
Oil & Tars							
Trace Elements							
Spent Catalysts							
Ash/Slag							
Filter Cake							

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This last emphasis was developed in Table 5. Here the principal change agents potentially introduced into the air and land media are listed down the page (leaving the water medium to the aquatic panels). The environmental levels of organization at which perturbations could result are listed across the top. In the body of the table the attributes which might usefully be monitored are listed, along with comments as to reasons for concern (or lack of it). This table was used as a basis for discussions with the source characterization panel in an attempt to define our research priorities through a better understanding of the expected volumes and concentrations of the agents in real-world terrestrial ecosystems.

This interaction was significant in several ways. In some cases we learned that there was no problem (oil aerosols). In others, however, source terms that we traditionally do not treat may require the greatest attention (COS and CS_2 under "Sulfur Compounds," Table 5). In still other areas problems that seemed under control, such as phenols in wastewater, may in fact not be; phenols could be entrained in cooling tower drift if untreated water is used as blowdown water.

Most importantly we learned that source characterization people were accurate when stating that in many cases they couldn't give us even a preliminary cut at the information we wanted (volatile organics and heterocyclics in solvents, products, solid wastes). Thus we have a chicken-and-egg problem, with biologists wanting the source characterization specialists to tell us which process streams have problem constituents and the characterization people wanting biologists to tell them which streams to look at for problem constituents. We concluded with a strong impression that we can progress only by working together. A major outcome of this exchange is illustrated in the way that the detail in Table 5 ran out when we discussed solid waste. Neither we nor source characterization scientists knew enough about this subject even to make guesses that would have contributed to completion of the table.

PROBLEMS AND RESEARCH NEEDS

Using all the information obtained by the above procedures, the panel created a list of high-priority problem areas on which to develop problem statements (see following page). Each panel member volunteered to develop problem statements on selected problems in his or her area of expertise. Each person was then charged to:

1) Write a succinct definition of the problem

2) Outline the information needed to solve the problem

3) Provide a generic discussion of the state of the art, listing a few of the most pertinent references

4) Identify that portion of the needed information which is not currently available as research needs

5) Recommend a research strategy, experimental designs and test organisms or systems for each such need as appropriate.

In addition, panel members were asked to address any other problems which they felt were important and might be overlooked. The following pages contain the responses of the panel members to this assignment.

Problem Areas Identified by the Terrestrial Effects Panel for Development of Statements of Research Needs. (In general, solid waste problems are given high priority, air emissions are given medium priority, and land use, low priority.)

Solid Waste	Air Emissions	Land Use
Characterization	Characterization (including transformation)	Dedicated
Transformation (physical, biological)	Baseline air quality	Reclamation
Transport, sorption, migration		
Food chain effects -uptake -translocation -accumulation -concentration	Effects -acute -chronic -subacute -synergistic	
Transfer to man		

BASIC RESEARCH PROBLEMS

Before outlining specific areas of needed research, it is important to review the state of the art of ecological baseline study methodology and data evaluation strategies.

Until now environmental studies have generally been qualitative descriptions of environmental settings and professional "best guesses" as to the expected level of impact. However, for new energy technologies with new types of expected perturbations, we must improve our method of basic environmental descriptions. If we are to predict with any degree of confidence how the new types of energy technologies may affect the terrestrial biological setting, we must use the best descriptive tools we have available.

A holistic approach is as applicable to major energy project developments as it is to establishment of predictive models for new types of chemicals introduced into natural biotic communities. It is through a rigorous systematic approach that we can best evaluate levels of expected impact. The following problem statements are intended to represent components of such an approach.

ECOLOGICAL BASELINE DEFINITION AND IDENTIFICATION OF RESEARCH NEEDS

Determining baseline conditions in the terrestrial ecosystem before constructing, operating, and closing a coal gasification/liquefaction plant will be difficult because of the chemical uncertainties. The general criteria for determining baseline conditions in and near a proposed site should be based on ecosystem components or processes that are likely to be affected by chemical and physical agents entering that ecosystem from the plant. States et al. (1978) present a systematic approach to choosing the components and processes to measure in a baseline study that are most likely to be useful in operational monitoring for adverse impacts.

Based on this assumption, the terrestrial panel devised a simplified ecosystem model (Figure 3) and used it to screen a list of source terms for each technology (Antizzo 1978), noting for each the point of entry into terrestrial systems and potentially serious ecological problems resulting. This approach became the framework for identifying and prioritizing research needs based upon the seriousness and extent of the impacts and our degree of uncertainty about controlling mechanisms.

Thus, three major problem areas associated with coal gasification and liquefaction were identified: air and water transport, solid waste disposal, and changes in land use patterns. The holistic approach for handling these problems includes:

1) Source characterization whenever possible, but a more empirical approach if necessary

2) Determination of likely receptors and pathways (Figure 3)

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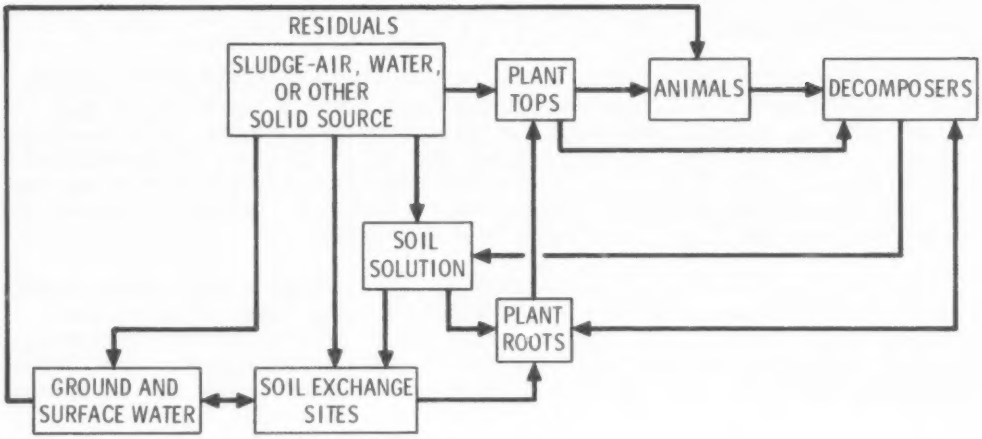
RESIDUALS
SLUDGE-AIR, WATER, OR OTHER SOLID SOURCE
PLANT TOPS
ANIMALS
DECOMPOSERS
SOIL SOLUTION
PLANT ROOTS
GROUND AND SURFACE WATER
SOIL EXCHANGE SITES

FIGURE 3. Simplified Ecosystem Diagram Used as a Basis for Anticipating Potential Impacts from Previously Identified Source Terms

3) Design of experiments to examine most responsive/sensitive parts of the system

4) Definition of needed input data from source characterization groups

5) Definition of our criteria for biological importance.

We still need more sensitive analytical tests, especially for the fate and effects of organics and trace minerals.

INVESTIGATORY DESIGN

The majority of research to date has been undertaken to establish cause-and-effect relationships. In environmental studies the research flow goes from cause to effect with some attempt to identify transitions that occur:

$$\text{Cause} \xrightarrow[\text{Direction of Research Flow}]{\text{Mechanism}} \text{Effect}$$

In medical research, scientists are also concerned about cause-and-effect relationships as well as the transition states that occur. The major difference, however, is that often the effect is seen before the cause is known. This results in a reversal of the direction of research flow:

$$\text{Cause} \xleftarrow[\text{Direction of Research Flow}]{\text{Mechanism}} \text{Effect}$$

though as scientists our job is to identify potential problems before they manifest themselves in order to mitigate any potential effects. Often we are called upon to diagnose the cause of an observed effect and prescribe an appropriate mitigating measure. Our hypothesis often misses the mark because we know neither the cause nor the transition state that has taken place.

These problems will become increasingly severe as more sophisticated technologies multiply and expand exponentially the potential source terms and transition states capable of causing the effect noted.

Discussion of the Problem

A plethora of good investigatory models are available but their applicability to present needs are tangential at best. Case studies will be required as large-scale coal conversion facilities are constructed and operated and more field problems are identified.

Research Needs

Needed research activities are to:

1) Examine interdisciplinary research designs and investigatory models to identify and develop those which allow us to anticipate and prevent potentially serious problems before they occur.

2) Test and improve models in a controlled field environment for evaluation of research time required and accuracy of results

3) Develop a nationally accessible computerized information system to support and aid in the diagnostics of selected investigatory models.

The independent conduct of this research, development and testing must be adequately supported so that this high-priority work is not subverted as a secondary or lesser issue in a larger study.

SOURCE CHARACTERIZATION

Discussion of the Problem

Potentially toxic forms of chemicals associated with coal gasification and liquefaction effluents identified as these forms enter the biota. Air and water quality experts should provide terrestrial ecologists with quantified estimates of the time-space dispersion and transformations of each chemical and physical compound expected to escape from the coal gasification/liquefaction technologies common to other energy-related processes, but for which acute, subacute, chronic, and biologically synergistic effects are little understood.

Research Needs

Research should address:

1) The interface between each transport medium and the biota

2) The specific processes or uptake mechanisms by which the biota assimilate these compounds

3) The bioavailability of these compounds as functions of temperature, humidity, pH, and other abiotic characteristics of the ecosystem that influence bioavailability

4) The biological transformation, transport, accumulation, and waste disposal of these compounds through the biological portion of the ecosystem.

INFORMATION TRANSFER BETWEEN BIOLOGISTS AND ENGINEERS

Discussion of the Problem

In the past, biologists and process engineers have shared little information aimed at preventing problems before they occur. An interdisciplinary approach is needed, however, if potential environmental problems associated with coal conversion processes are to be identified and dealt with effectively.

In one sense there is a stand-off between the two groups in addressing coal conversion problems. Process engineers are asking: Which agents of those that might issue from the various processes are the potential problems? And to what level must they be controlled to prevent the problem? Biologists, on the other hand, explain that they cannot give answers until more specific questions are asked; predicting effects requires complete characterization of pollutant agents at the point where the receptor is impacted, as well as knowledge of the site-specific biota and meteorological conditions.

The black box between these two viewpoints contains transport/transformation and temporal/spatial factors. Also in the box is the complex array of pollutant mixtures that may result from the interaction within ambient media of discharges from several process streams or from combined discharges originating from multiple sources. The precise mechanisms occurring in the black box cannot be known until a full-scale conversion facility is operational and perhaps not even then. However, using predictive modelling techniques, some good approximations can be made (particularly with regard to atmospheric emissions) of the dilution that will occur between source and receptor. Therefore, currently available source characterization data, even though incomplete and uncertain, when coupled with dispersion modelling, is sufficient for terrestrial effects evaluation, at least as a first approximation in an iterative process. This would be valuable because it would help direct the choice of best alternatives in process design and help to direct additional source characterization into the most sensitive areas.

Communication between biologists and engineers can help both sides to approach the state of knowledge of potential problem agents from their respective vantage points, and thereby to extend their common knowledge.

STATISTICAL PROCEDURES

Discussion of the Problem

Laymen and administrators alike will want to know what environmental disturbances are correlated with each gasification or liquefaction activity. However, the mechanism connecting the observed activity to a presumed effect may occur within living cells and not be directly observable. In such circumstances, the best we can hope for is a strong relationship between Event A (the possible cause) and Event B (the possible effect). If such a relationship exists we tentatively accept that A causes B unless additional information is gathered which casts doubt on this conclusion. Where variations in the supposed cause are not exactly matched by variations in the effect we use the laws of probability, as applied through the science of statistics, to help us decide whether or not there is sufficient evidence to support the hypothesis that a real relationship exists. These decision-making procedures should be reviewed and revised to better serve the particular needs of environmental scientists.

There is already a large body of information on statistical analysis and experimental design and some few of these are directed at the specific problems encountered in the process of impact assessment. Two major problems exist in the application of this information. One is that appropriate statistical procedures and assumptions are often not used *a priori*, or are applied after the research has been done. This should be more uniformly required of all environmental research, especially in the experimental design stage. The second problem is that most statistical theory is based upon the assumption that a Type I "producer's risk" error is the most serious type of error one can make in statistical decisions. But from an environmental standpoint a Type II "consumer's risk" error is the most serious. This would be the type of error made if one accepted the hypothesis that a given industrial effluent caused no ecological changes when in fact it really does. By making this kind of mistake we give a green light to process engineers and serious consequences may ensue.

Research Needs

The connecting mechanisms for industrially caused environmental changes may go through a complex chain of cause-and-effect events before surfacing in observable and potentially dangerous ways. Further, an observed environmental change, such as a population crash, can often be brought about by a wide variety of naturally occurring events such as changes in precipitation and low food supplies. Given these complexities, considerable thought and research should be given to modifying the application of statistical theory to environmental decision-making. In particular, additional research is needed in:

1) How to better estimate variation in man-caused disturbances

2) Increased emphasis on procedures for field validation of impact predictions made from laboratory results or professional intuition, which is the major vehicle for improving our predictions and improving our control over adverse environmental effects

3) Investigation of the implication that greater risks are associated with Type II errors. In all likelihood this total reorientation of hypothesis-testing will lead more to the establishment of critical limits and safety margins for pollutants which are useful to the regulatory process. These limits would probably have a very large range in the beginning, when we have little hard data, and will be narrowed down as research provides more amd more information.

CHARACTERIZATION PROBLEMS

PROCESS WASTES

Introduction

Significant chemical characterization of process streams in coal conversion facilities has been accomplished over the last few years. This work and the majority of solid residual studies, however, have not dealt with disposal and handling of transient materials from process failures, shut-downs and maintenance efforts. Similarly, selective leaching tests that more closely resemble the leaching effects in the natural environment have not been developed. The issues relating to the handling and transporting of these wastes have been only peripherally dealt with in recent years. Yet issues of solid waste handling, disposition and ecological effects assessment may be the most demanding research areas in the next decade.

Discussion of the Problem

In any given coal conversion process there are a range of solid waste residuals produced. Some are produced regularly with a high degree of consistency in physical and chemical make-up. Other wastes are highly variable, infrequent in production, and potentially most dangerous to the ecosystem.

Wastes noted in the former case are residuals, such as ash/slag or scrubber sludge, as discussed above. Wastes in the latter case result from a process malfunction or mishap. These are generally process wastes; that is, wastes that typically are part of a processing step and are not commonly handled. For example, if a valve, pump, or line fails, large quantities of partially reacted materials may be stopped at an intermediate step in the process. These wastes might be under high pressure and at high temperature and could seriously threaten the safety of the operation. If these wastes must be removed from the system for safety or for any other reasons (i.e. cleanup, maintenance, etc.) the handling and disposition of these wastes in an environmentally sound manner becomes a significant problem.

These wastes can be handled in several manners:

1) Incineration. This may produce a toxic and concentrated, less voluminous ash for land disposal as well as a potential air pollutant.

2) Direct land disposal without volume reduction techniques. This requires handling of a larger volume of wastes and presents a severe containment problem. There is an inherent risk in the greater potential for POM to enter the aquatic environment.

3) Segregation of wastes for selective incineration and land disposal. This would reduce the quantity of wastes and is a compromise between incineration and disposal.

4) Reuse of wastes. This would require segregation and characterization as well as the application of the above items in final disposal of those materials not determined reuseable.

Development of appropriate physical and chemical analysis techniques to do accurate Ecosystem Effects Assessments (EEA) is also a problem. EEA differs from typical chemical characterization studies in that the only substances evaluated in waste materials are those that would impact on the ecosystem once the material was disposed. Solid waste materials are usually characterized through leaching experiments. Unfortunately these experiments usually result in leaching all materials, including those in the fill material as well as those in the solid waste. Such experiments do not mimic natural leaching processes. For example note the diagrams in Figure 4.

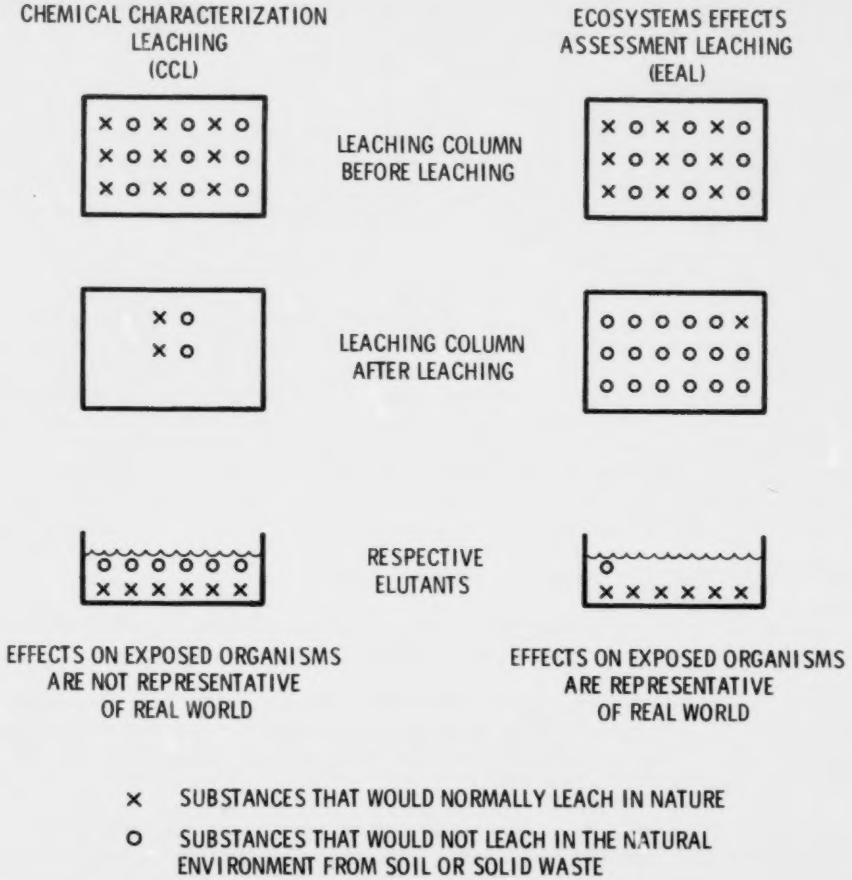
CHEMICAL CHARACTERIZATION LEACHING (CCL)
ECOSYSTEMS EFFECTS ASSESSMENT LEACHING (EEAL)
LEACHING COLUMN BEFORE LEACHING
LEACHING COLUMN AFTER LEACHING
RESPECTIVE ELUTANTS
EFFECTS ON EXPOSED ORGANISMS ARE NOT REPRESENTATIVE OF REAL WORLD
EFFECTS ON EXPOSED ORGANISMS ARE REPRESENTATIVE OF REAL WORLD
× SUBSTANCES THAT WOULD NORMALLY LEACH IN NATURE
O SUBSTANCES THAT WOULD NOT LEACH IN THE NATURAL ENVIRONMENT FROM SOIL OR SOLID WASTE

FIGURE 4. Difference Between Chemical Characterization Leaching and Ecosystem Effects Assessment Leaching, Using Two Chemicals, X and O

Subsequent analysis of these elutants would show significant variation and result in widely divergent recommendations as to handling of these wastes and the hazards associated with each. The real potential for significant expenditures in resources and energy in disposing of the materials that would be stable in nature based on a CCL analysis must be avoided. There is a need for leaching techniques that will elute only those materials that would be released in a real-world situation.

Another problem is the handling of the wastes by workers. This issue merits mention because of the need to develop characterization and segregation techniques to identify the hazards in any given waste. On a short time basis, in order to handle spills of product or process solid waste rapidly and efficiently, special procedures and color-coded flow diagrams will need to be developed. These pre-event contingency plans, plus proper training of personnel in handling a spill or process failure, will greatly reduce the hazard to the workers, the public at large, and the environment.

Licensing of disposal sites and selection of contractors to dispose or haul these wastes must be done with care. Plans which disposal site operators and haulers have for dealing with the hazards associated with these wastes must be carefully assessed.

Research Needs

Research is needed, therefore, toward the following ends:

1) Development of appropriate representative leaching tests and chemical characterization techniques for product and process waste materials

2) Development of techniques for rapid classification and segregation of product or process components of wastes

3) Technical advances in volume reduction techniques

4) Full discussion of product/waste reuse and specific recommendations for additional studies defining reuse or recycling of these wastes to improve not only the net energy balance of these facilities but also to maximize resources available

5) Specific recommendations for handling, cleanup, reuse, and disposal of wastes and products from coal conversion processes on a process-by-process basis as well as on a product-stream basis to insure rapid, efficient and safe response to spills or disposal events

6) Expansion of toxicity testing rather than chemical characterization of waste and product streams to the macroenvironment

7) Successful modelling of the identified product/process waste streams for prediction of the effects of "class of compounds" or specific compounds on a complex ecosystem

8) Re-evaluation of the Resource Conservation and Recovery Act as well as the Toxic Substances Act in light of the results from the research identified above.

PHYSICAL AND BIOLOGICAL SOLID WASTE TRANSFORMATION

POLLUTANT MIGRATION FROM DISPOSED SOLID WASTES

Discussion of the Problem

The characteristics of pollutant migration from the disposed solid waste of coal conversion processes constitute a major unknown. Solid waste material is certain to be transferred from disposal sites to terrestrial receptors. It is generally agreed that water is the primary transport medium through which this transfer will take place. Pollutant migration from disposal sites will be influenced by such site-specific factors as climate and weather, soil characteristics such as ion exchange capacity, terrain, design of disposal site, and groundwater overburden. Qualitative and quantitative characteristics of the disposed material will also influence its transport. Not only the specific chemicals and elements in the waste but also the complexes formed, rates of degradation, and pH must be considered.

Aqueous discharge from solid waste disposal sites, unlike emissions to the atmosphere or aqueous effluent introduced to surface waters, is best viewed as a plug-flow process. Chemical processes will take place within the leachate as it moves through layers of soil. Its movement may be either lateral or vertical depending on the specific geology of the site. A disposal site will be systematically opened, filled, closed, and ultimately abandoned. This means that insults from a given site to the terrestrial environment will change with time.

Research Needs

The patterns of pollutant releases to the environment over time should be studied. This is probably amenable to computer simulation on a pollutant-by-pollutant basis. Parameters influencing rates of pollutant release must be identified.

This information would provide the basic data needed to determine whether contemplated solid waste disposal techniques are acceptable. Alternatively, it may indicate that altering traditional disposal techniques can increase the environmental acceptability. For example, selective predisposal leaching may be required for certain kinds of pollutants.

TRANSPORT/TRANSFORMATION OF TERRESTRIAL POLLUTANTS IN A LIQUID MEDIUM

Discussion of the Problem

Because the primary transport/transformation medium for chemical compounds into the terrestrial biota will probably be water, we must examine the movement and transformation of these compounds in surface and subsurface flows to identify potential interactions with the biota.

Transformations will occur under different physical conditions such as temperature or pH. These must be systematically investigated for all potentially toxic chemical species, along with the interacting effects of soil particle size, texture, and physical materials; e.g., acid in limestone soils.

Reinjection of solid and liquid wastes may seriously affect the quality and quantity of water in aquifers, as well as subsidence. Seepage of this water into the root zone of plants and into surface water in openings would bring contaminants into the food chain through plant uptake and animals drinking water or eating plants with uptaken chemicals.

Movement of toxic ions through the soil matrix, with attendant problems in the decomposer trophic level (soil microbes, invertebrates, etc.) will pose problems.

Research Needs

There is a need to develop basic research, first in the laboratory and then at field disposal sites, on the factors affecting pollutant mobilization, transport and transformation for solid wastes representative of coal liquefaction/ gasification technologies.

TRANSPORT FOCUS

Discussion of the Problem

In discussing terrestrial effects it is important to note that it is not the air pollution nor the solid wastes per se that in and of themselves cause a direct effect. Rather it is whether or not the materials are rendered into a state that allows them to be brought into the ecological web.

In virtually all instances these pollutants must be carried or dissolved into a liquid medium that can be adsorbed by the organism or its tissue. Surface adherence of toxic particles on exposed tissue is toxically effective only if they can be adsorbed into the surrounding tissue. The mechanisms involved in this adsorption process may include temperature, chemical reactions to form intermediate compounds that can be adsorbed, deabsorptions of the particle, pH, and solubility characteristics to name a few.

The focus of current pollution effects studies should be narrowed to deal mainly with that portion of the residual that can be carried or dissolved into a naturally occurring liquid medium and adsorbed by the organism and its tissues. Chemical characterization and toxicity studies to date have not dealt in any significant manner with what is transported and what is ultimately adsorbed by an organism or tissue.

Research Needs

Research should be directed toward the following:

1) More in-depth information on the solubility of the products and byproducts of coal conversion processes into naturally occurring liquid media

2) Development and careful definition of an adequate data base, preferably computerized, that deals exclusively with the chemical kinetics of coal conversion residuals and products in enhancing, delimiting or reducing solubility

3) Development and application of appropriate selective analytical techniques for defining the level and type of contaminants adsorbed into any given ecosystem apart from those constituents remaining in the residual or product that are nonreactive in a biological system.

SOLID WASTES: SOIL INTERACTION INCLUDING TRANSFORMATION, SORPTION, AND MIGRATION

Discussion of the Problem

Effluents from solid waste deposits will be transported through the soil by water. The results of interaction of coal conversion and related contaminants (especially organics) with soils are largely unknown.

Soils are major sinks for contaminants released to the terrestrial environment. The behavior and fate of recognized organic contaminants must be evaluated in terms of 1) the capacity of soils to retain effluents; 2) the capacity of soil to catabolize effluents; 3) the physicochemical interactions between contaminants and soil constituents and the manner in which such interactions affect persistence, leaching and volatilization; and 4) the routes of transfer to biota. This information can be integrated into a determination of the relative hazard of a substance in comparison to existing recognized health hazards.

Research Needs

Several types of data are needed. They are 1) persistence evaluation (including catabolites), side effects on soil microbes, and determination of soil degradation potential; 2) adsorption, leaching and volatility testing to assess the most probable routes of physical transport to the biological receptor and 3) biological availability tests and environmental factors affecting availability to plants. These data would provide the basis for assessing physical persistence of the parent compounds, appearance and persistence of catabolites, probable routes of exposure to biota, and availability to biota.

The methodology to acquire these types of data is available. Information from the environmental testing of pesticides could be used. Additional research needed would specifically address the major compounds or classes of compounds in effluents from coal conversion solid waste disposal sites.

Experimentation is needed on soil retention, degradation potential, physicochemical interactions and biological availability. The techniques for these experiments are generally available but need modification to meet the specific needs of coal conversion. These data would yield direct information with which to assess the persistence and availability of potentially toxic substances from coal conversion emissions or residual streams.

ENVIRONMENTAL CHEMISTRY OF POLLUTANTS

Discussion of the Problem

Large volumes of pollutants enter the environment through solid waste disposal. Aside from the large areas of land (either mines or alternative dumpsites) affected by this, the disposal of soluble pollutants through groundwater into surface streams or through transpiration into surface vegetation may be a major problem. The physicochemical and biological transport, fate and effects of these materials, as modified by the local environment, represent as complex a set of problems as has ever been studied by environmental scientists.

A central problem in performing generic research on solid waste is the extreme dependence of transport, fate and effects of pollutants upon local climate, topography, soil structure and chemistry and groundwater hydrology. Nearly all movement of solid waste pollutants happens through a liquid medium as solid waste leachates. In order to predict biological effects we must know what governs leachability, transport and physicochemical transformations of the leached materials. This information will be useful to the stabilization and reclamation of disposal areas. Thus it is important to initiate studies at two extremes along several important environmental gradients (arid versus mesic environment, sandy/low nutrient versus clay/high nutrient, low pH versus high pH), enabling researchers to interpolate predictions to a particular demonstration or commercial site presenting conditions lying between such extremes. These variables need to be investigated in relation to several soil treatments and overburden/waste/underburden conditions.

Research Needs

For research on this problem, a principal solid waste stream and its important variants should be identified for each technology. Then for each variant, the following should be done:

1) Physical and chemical characterization of leachates

2) Observation of chemical and microbiological transformations with time, and of transformations as transported through materials representative of possible extremes of overburden/underburden, climate and soil treatments

3) Incorporation and accumulation or concentration of leached materials in plant and animal tissues

4) Biological characterization of leachate effects at relevant levels of biological organization.

A suggested generic research project would be to rank the solid waste streams of a given technology according to potential for environmental damage. For at least the streams of highest priority and their important variants, two or more points on important environmental gradients should be examined. These would include gradients in precipitation regime, soil temperature, overburden/topsoil treatment, soil nutrients, soil pH and the like. For each chosen variant the next step would be to find physicochemical information on leachates and their alterations over time and transport through other materials, and to investigate the biological fate and effects of these materials in terrestrial vegetation and through associated animal food webs. This investigation would concentrate on organics and organometallic complexes because their efforts are least understood. Predictive models would then be developed for estimation of problem potentials from each of a number of solid waste disposal options.

Site-specific research would follow. When a site is selected for a demonstration or commercial facility, predictive models can be verified and improved on a site-specific basis. Real data would be incorporated for certain estimators such as hydrologic sources, rates and avenues of movement and release to surface water.

FOOD CHAIN EFFECTS OF SOLID WASTES

EFFECTS OF AIR EMISSION AND SOLID WASTES

Discussion of the Problem

Routine emissions to air and disposal of wastes from all types of coal conversion facilities transport and cycle effluents within terrestrial ecosystems. This cycling can lead to accumulation (e.g., of trace elements) in biota with the resultant risk of acute (low priority) and chronic (medium priority) effects. It is also possible that combinations of subacute levels of accumulation could act synergistically to affect biota. With accumulation there is also the possibility of biomagnification through the food chain. This is especially true for trace levels of exotic organics and heterocyclics (high priority).

The release of effluents to the environment results in their dispersion. Based on effluent transport and transformation, the partitioning of pollutants into the environment around coal conversion sites needs to be determined. Ultimate levels of effluents in biota and their effects must be determined under controlled exposure conditions at both individual and population levels. In the absence of complete pollutant characterization, marker compounds or elements should be employed. Food chains should be examined experimentally and any effects (or bioaccumulation) noted should be related to the exposure conditions and in turn to the rate and volume of release for the source stream.

Research Needs

Several types of data are needed to directly assess the level of effects on biota. These data concern:

1) Effluent (transformation product) distribution in affected (experimental) ecosystems

2) Effects at the population, organism, and physiological levels

3) Food chain and chemical contact effects

4) Experimental results on subacute concentrations of multiple stressors on biota.

There is already a significant amount of data for trace elements, but almost none on effects of low levels of exotic organics. Much of the trace element effects information would transfer directly. However, experimental work is needed on effects of trace organics and combinations of low (subacute) levels. Trace elements that still need attention are mercury, selenium, cadmium and fluorine.

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Laboratory and field experimental studies of effects on biota (plant, animals, microbes) of toxic materials from coal conversion solid wastes are needed. The experimental plan could follow the generalized top-down strategy explained in the Overview of this report. A task of lower priority is similar experimentation, guided by monitoring results, on fugitive and routine air emmisions. These projects would directly yield data delineating adverse ecological effects.

ACCUMULATION AND CONCENTRATION OF SOLID WASTE POLLUTANTS IN TERRESTRIAL FOOD WEBS

Discussion of the Problem

Solid waste disposal products contain inorganic and organic substances toxic to biological organisms. Some are carcinogenic and others have the potential for biological perturbation but their effects are unknown.

To systematically and effectively identify toxic elements in solid waste, one must evaluate the methodology of waste disposal, the relative availability of toxic substances to organisms and the transfer and/or accumulation or amplification of the substance within subject food chains. Figure 5 illustrates the pathways through which toxic substances from solid waste may flow within a terrestrial biological system.

The conditions promoting chronic accumulation and amplification of toxic substances must be studied. This problem is particularly important because toxic effects may not surface for many years; they may be detected only by a slow change in population dynamics or altered community structure, and/or a shift in ecosystem dynamics. A case in point is the latent effect of DDT in raptor eggs, which took perhaps 20 years to be identified.

Several possible manifestations of solid waste impact on the terrestrial biotic system are:

1) Sterilization of soils

2) Alteration of soil microflora and fauna

3) Effect on vascular vegetation resulting in alteration of vegetative associations and communities

4) Toxicity of primary consumers via translocation of toxic substances from vegetation

5) Accumulation and amplification of toxicants to secondary and tertiary consumers.

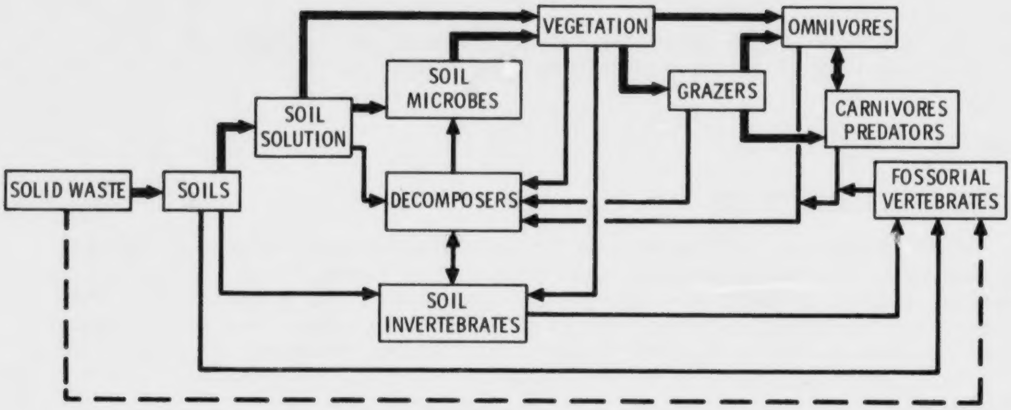
SOLID WASTE
SOILS
SOIL SOLUTION
SOIL MICROBES
VEGETATION
DECOMPOSERS
SOIL INVERTEBRATES
GRAZERS
OMNIVORES
CARNIVORES PREDATORS
FOSSORIAL VERTEBRATES

FIGURE 5. Pathways Through Which Toxic Substances May Flow Within a Terrestrial Biological System. The heavy line indicates a hypothetical flow through which biological amplification and accumulation might often take place.

Beginning with Step 2 above, any change in the established biotic community will be manifested throughout the system; it will cause a "ripple" effect. The magnitudes of the ripple through the established community structure, that is, the extent to which the rest of the community is affected, will be a function of the original stability or "equilibrium" of the community.

Research Needs

Thus, the problem is reduced to identifying those species of elements and compounds, organic and inorganic, expected to occur in solid waste. The research should then be designed to answer the following questions:

1) How toxic is each element or compound?

2) What concentrations of each are reasonably expected to occur?

3) What is the availability of each to biotic entities?

4) To what organisms or at what level within the biological/ecological system is each expected to manifest itself?

5) What are the organism and system threshold limits of each?

6) How much time will elapse before adverse effects are detectable?

7) Are secondary chemicals likely to occur via chemical reactions within the waste or soil media?

8) Can alternative procedures be taken to reduce the toxicity or availability of these chemicals to biotic species?

TRANSFER TO MAN

Discussion of the Problem

Coal conversion (all types), while regulated to meet state and federal air and water quality standards, will release small amounts of effluents from fugitive sources as well as from routine operations. These effluents, both organic and inorganic, will be dispersed in the environment and will probably enter critical pathways leading to man: inhalation, drinking water and food. This could increase exposure and accumulation of potentially harmful trace substances.

Research Needs

The food intake pathway should be the focus of a major research effort in order to identify the terrestrial effects most significant to man. Three principal types of data are required:

1) identification of the critical environmental pathways leading to man

2) monitoring of substance flows along these pathways

3) suitable analytical models to assess exposure and accumulation in the individual and in the population.

These data and models provide the means to quantify man's exposure to effluents from the coal conversion industry via environmental pathways.

Further research is needed on environmental dispersion from operating coal conversion facilities. Models of radionuclide dispersal along critical environmental pathways provide a starting point for developing comparable transport models for coal conversion effluents. However, there is no question that additional model modification and development would be required.

GASEOUS AIR EMISSIONS

Ambient concentrations of toxic gases and particulates emitted from a single gasification or liquefaction unit are not likely to cause significant adverse effects away from the plant site. The primary concern is their incremental effects on already substantial background levels. On regional sites these increase the number and magnitude of chronic ecological effects attributable to the SO_x-NO_x-oxidant-particulate pollutant complex acting through both wet and dry deposition.

Research priority should be given to evaluating chronic exposures of agricultural and natural ecological systems to this pollutant complex. While a substantial body of work has dealt with acute exposures of some pollutants and pollutant combinations to crops, little work has been done to identify chronic effects under realistic exposure regimes. Part of this problem results from lack of air quality data that statistically describes realistic exposures. Researchers need air monitoring data thorough enough to indicate the functions and range of parameters that adequately describe realistic exposures. Joint distributions of pollutants are also of concern.

THE EFFECTS OF EXPOSURE TO GASEOUS POLLUTANT MIXTURES

Statement of the Problem

Pollutants exist as mixtures in the environment. Only limited studies have been conducted on the effects of pollutant mixtures in biological systems. In several studies the effects of the pollutant mixture were greater than would be expected from the sum of the effects of individual pollutants. Research should be conducted to assess the general importance of synergistic effects.

With the projected increase in SO_x, NO_x and probably in O_3, the likelihood of effects from these pollutant mixtures should be studied. With our present limited data base, the magnitude of these effects cannot be estimated.

Research Needs

Information is needed on the following:

1) Statistical descriptions of required background concentrations at ecological receptors of pollutant mixtures

2) How qualitative and quantitative pollutant mixture variations in time and space should be identified.

Such studies should focus on transport, transformation chemistry, SO_x, NO_x, and oxidants.

This would make pollutant spatio-temporal variations more available for conventional gaseous pollutants, which in turn allows experimental exposures to important ecological receptors to be made more realistically. Bounds could be placed on the numbers and types of experimental exposures needed. Much of this information is probably already available but not in usable form. For areas where conventional pollutants (SOx, NOx, oxidants) have been monitored for long periods, this information should be summarized to provide meaningful guidance to experimental chronic exposure studies.

Research should therefore be directed toward development of detailed chronic background exposure regimes for major biological systems from existing air quality data. Simulation models should then be developed which are capable of predicting temporal patterns of pollutant mixture combinations at ecological receptors, assuming different source configurations. This will allow structuring of meaningful experimental exposure regimes for ecological receptors.

Additional research projects are chronic exposures of important biological systems to realistic pollutant combinations: 1) laboratory and field exposures to elucidate effects on key organisms (crops and important ecosystem components) and 2) experiments on the most sensitive and important species to elucidate modes of action and to develop predictive models. This research will allow prediction of effects assuming different realistic pollutant mixtures under different development scenarios.

THE BIOENVIRONMENTAL EFFECTS OF EXPOSURE TO CARBONYL SULFIDE (COS)

Discussion of the Problem

Coal gasification facilities may emit substantial quantities of COS. Very little study of the ecological consequences of these emissions has been made. Both acute and long-term chronic effects of COS exposure should be evaluated.

Preliminary data indicate that acute fumigations (1 hr) at COS concentrations of 0.5 to 1 ppm cause severe reductions in photosynthesis in Phaseolis vulgaris. Repeated fumigations lasting 1 hr at 30 ppm COS yielded no consistent effect pattern. Thus COS may not be as toxic as SO_2 in acute doses. The consequences of chronic exposure are completely unknown. Dose-response information must be generated for chronic exposures to a variety of vegetation and animals. We need to understand the physiological mechanisms by which COS may affect living organisms.

Research Needs

Dose-response information is needed for COS on a variety of organisms important to agricultural and natural systems. Realistic exposures must be derived from transport/conversion information. Also of interest are the effects of realistic exposures of a) yield of commercial species, b) population parameters of key species in natural ecosystems and c) attributes of ecological systems most likely to be impacted, i.e., natural systems near coal fields. Except for limited work on acute exposure of *Phaseolis vulgaris*, we know of no relevant research in progress.

Research Needs

An appropriate research project on this problem would be to evaluate the statistical properties (i.e., magnitude, frequency and temporal autocorrelation) of pollutant exposures in the vicinity of coal gasification plants at the receptors (select best canopy height or other appropriate sampling points most relevant to ecosystem function). An evaluation of this sort would provide realistic exposure to guide decisions for experimental exposure of appropriate organisms.

The best available dispersion/transport/transformation models could also be used to predict realistic exposures near gasification plants. This would allow experimental exposures to proceed before a conversion plant was operational. It would also allow evaluation of effects of various plant designs on air quality.

Another topic of research could be the responses of biota to realistic exposures of COS. This research could especially focus on physiological modes of action and those responses which are economically important (such as changes in yield). It would give a first approximation of the magnitude and importance of the effects, show where the important effects occur, and help to identify underlying causative mechanisms that must be understood so that results can be extrapolated.

ESTABLISHING A BASIS FOR IDENTIFYING CHANGES IN AIR QUALITY AND THEIR EFFECTS

Discussion of the Problem

In order to detect changes in air quality and their environmental effects we must have baseline data on air quality parameters before the new pollutants are introduced. If this is properly done before a coal conversion facility goes into operation, careful consideration must be given to identifying potentially problematic materials and the method and frequency with which they should be measured both before and after the facility begins operation. It is as important to establish variance, ranges and the timing of peak concentrations as it is to establish averages. If data are gathered on a suspect air pollutant after operations begin without baseline data having been collected we can never gain a historical perspective. When we have no baseline data we must rely on experimental manipulations (such as correlation of biological effect gradients with pollutant emission gradients) to separate pollutant-induced from naturally occurring events.

Because we cannot always anticipate which pollutants (especially those from new technologies) may be problematic, it is surprising how little attention has been given to the storage or banking of preoperational samples for subsequent analysis.

Research Needs

Often new energy facilities are begun without adequate baseline data on preoperational environmental conditions. We cannot emphasize enough the need to conduct systematic baseline studies which effectively anticipate potential air quality problems.

Methods need to be developed for banking samples from high volumes of air on appropriate types of filters. This would be a basis for checking preoperational concentrations of materials identified as possible problems after plant start-up. Both laboratory and real-world investigations should be instituted to test the effects of new pollutants resulting from new technologies.

THE BIOENVIRONMENTAL EFFECTS OF EXPOSURE TO TOXIC PARTICULATES

Discussion of the Problem

The effects of toxic chemicals associated with fine particulates are poorly understood. However, we do know that trace elements of greatest potential toxicity for plants are boron, cadmium, cobalt, chromium, copper, fluorine, nickel, thallium and vanadium. Elements of particular significance to animals include beryllium, cadmium, fluorine, mercury, nickel, antimony, selenium and thallium. The five elements with overall greatest potential impact on terrestrial biota are cadmium, nickel, thallium, copper and fluorine.

PAH's associated with particulates are also of concern. PAH's are active in metabolism, many of them being carcinogenic for animals breathing fine particulates. Available information suggests that effects on fish may be observed in water dilutions as low as a few parts per billion. Soil is an important sink for particulates and it is affected as well. Trace elements may change metabolism of microorganisms which in turn affects litter decomposition.

Research Needs

Effects of particulates from coal gasification plants which need to be studied are:

1) Concentrations of PAH's and trace elements in crops

2) Relationship between particulate exposure to vegetation and effects on consumers of the vegetation

3) Direct effects on animals respiring these particles

4) Effects of particulates on decomposers

5) Determination of how these compounds are metabolized.

This would allow evaluation of ecological effects of particulate complexes without detailed knowledge of their composition.

LAND USE

DEDICATED LAND USE

Discussion of the Problem

Coal conversion facilities of all types require large land areas for the conversion plant proper and supporting operations. This requires an assessment of the impacts on land use, hydrology and wildlife of the region. As a research requirement, this is a lower immediate need as these studies are required for the environmental impact statement process. Research is needed, however, on better approaches to such studies. These approaches should better treat the whole range of possible source terms and their effects on land use alternatives.

Siting of coal conversion industries should cause minimum damage to the surrounding region. To facilitate this, siting criteria should consider total land requirements, compatibility with existing land use patterns, habitat loss and modification, consumptive water use in relation to existing hydrology, and water quality of recycled water in relation to baseline water quality. This information forms the basis for judging the consequences of facility siting and criteria for judging environmental acceptibility of alternate sites.

Additionally, long-term effects of groundwater mining need to be assessed. This is particularly true in xeric environments.

Research Needs

The types of data required for this study are current land use distribution, surface water availability and current demand; groundwater availability and use, water quality and major wildlife species density and habitat requirements. These data form the basis for assessment of regional impacts.

Data on current land use distribution may be adequate on a gross scale, but detailed land use data are probably needed for evaluating alternate sites. Data on quantity of surface water are probably adequate; however, baseline water quality data are spotty. These missing data would be required for alternate site evaluation. The RARE II studies in progress will probably be sufficient to identify "exclusion areas," areas particularly sensitive because of wildlife and ecological attributes. At a regional scale, groundwater supplies are fairly well known, but details of groundwater supplies would have to be determined before evaluating specific alternate sites. Therefore, we recommend making surveys on land use, wildlife, and groundwater supply. More complete water quality data should also be collected, especially concerning total salts, trace metals and trace organics.

This sounds like an argument for developing large environmental reports replete with tables of useless data. To the contrary, we strongly recommend that each site evaluation program begin with a careful identification of the relatively few bits of information needed for sound decision-making and that only those data be gathered and reported.

RECLAMATION

Statement of the Problem

Coal conversion facilities of all types will generate considerable residual streams consisting of refuse from coal cleaning, ashes, slags and chars from conversion processes and sludges from water and flue gas treatment processes. These wastes will be disposed of in landfills or other types of surface operations. The disposal sites, when filled, will need to be stabilized and returned to some use without environmental damage. Their use is of great importance and will guide reclamation efforts.

Considerable research is in progress or completed on means to reclaim disturbed land, primarily from coal extraction. Much of the knowledge gained thereby should apply to stabilization of waste disposal areas. The particular disposal site must now be physiochemically characterized and existing reclamation strategy matched to specific characteristics of the disposal site. With successful stabilization, there is then the longer-term problem of insuring against loss of waste from the site via hydrologic transport uptake via vegetation, or biological transport via food chain pathways. This is analogous to disposal of low-level radionuclide wastes.

Research Needs

Data are needed primarily on the physical and chemical characteristics of individual disposal sites, and on the efficacy of various accepted reclamation strategies in different environments. The latter, of course, implies a need for developing and testing criteria for choosing appropriate reclamation practices for specific sites. The effects of stabilization on the fate of wastes must also be determined.

Site-specific surveys as described in the previous section on dedicated land use are appropriate for site characterization. Other research should be directed toward testing reclamation strategies and surveying stabilized sites to determine the extent to which stabilization aggravates waste migration through increased percolation and leaching or biological uptake. Uptake and loss via leaching must be monitored. Mitigative measures to reduce loss, such as are used in low-level nuclear waste practices, can probably be employed.

MODELLING AND MICROCOSMS

The uptake and accumulation of solid waste material into the food chain needs to be approached from a systems viewpoint. The need for more satisfactory mathematical models coupled with the usage of experimental systems (microcosms) that are reflective of real-world processes is advocated as the only practical approach to a complex set of problems.

Discussion of the Problem

This approach is one strategy for addressing potential pollution problems generated by a developing energy technology. Terrestrial food chains may be considerably affected by solid waste pollution from coal gasification/liquefaction technologies. Regardless of how solid wastes reach the soil, a number of biological problems may result. First, the wastes and/or their metabolites may be bioaccumulated and the material subsequently translocated within the organism, as ingested cadmium is translocated to and stored in the liver and kidney. Also, as waste is passed through the various levels of the food chain, it may undergo either in vivo or in vitro (abiotic) chemical transformations. In either case, the original waste product has been changed into a new chemical which may have a different potential for accumulation and concentration. The uptake, translocation, accumulation and concentration of chemical substances are rarely viewed as discrete processes but rather as interconnected and dynamic within the total ecosystem under study. In some instances these component processes can be usefully analyzed as if they were distinct and separate entities. However, the responses of greatest significance are those which have implications to the entire ecosystem.

A research strategy that can help address these problems involves mathematical modelling of terrestrial systems that may be impacted by coal conversion facilities. Predictions made using these models are then tested at levels which at least partially reflect the real world. Experimental systems which should be strongly considered for this purpose are microcosms. A microcosm represents a simplification of natural ecosystem conditions which can serve to validate and refine model predictions, as discussed below.

Mathematical Modelling as a Research Approach

A systematic approach aids in application of mathematical models developed to explain changes in the ecosystem. The mathematical models applicable to describing the dynamic change of pollutants within systems may be classed as either deterministic or stochastic. Deterministic models describe the behavior of one system state from its directly precedent state with unit probability (Patten 1971). In this class of models, initial input values are known or estimated. As a result, the solutions obtained will be exact or determined. Stochastic or probabilistic models differ fundamentally from deterministic ones because initial values are viewed as being derived from a probability distribution and therefore the solutions obtained will also represent probability distributions.

To date, most ecological modelling has been done with deterministic systems. However, complex dynamic phenomena such as pollutant uptake and movement within food chains are probabilistic in nature, and thus the development of stochastic models, which realistically assess initial, midstream and terminal state changes as probability functions rather than as exact solutions, may be preferred. Both deterministic and stochastic models can be used to predict how real-world or simulated real-world (microcosm) systems change. When combined, models and microcosm experiments are very useful in predicting adverse pollutant effects before full-scale plant operations. For example, it has been shown that when cadmium, a heavy metal constituent of coal conversion wastes, is deposited in the soil, it is taken up and preferentially translocated to the leaves (rather than to the fruit or grain) of certain edible plants where it accumulates. Many other contaminants have yet to be so characterized. Studies using artificial agrarian-type microcosms with various solid waste contaminants could help greatly in predicting the degree of body burden that might accrue to man from ingesting various food plants polluted with such waste materials.

The abiotic factors that govern uptake of solid waste pollutants from the soil also need greater investigative attention. Again using cadmium as an example, it has been shown (Chaney 1977) that on certain crops uptake can often be directly related to the alkalinity or acidity of the soil. Uptake is greater with increased acidity. Other experimental studies on wheat demonstrated that the percentage of polynuclear aromatic hydrocarbons taken up by growing wheat was lower than that found in the soil used for the experiment (Graff and Diehl 1966).

There are several cautions to consider before using microcosms. One is that such artificial systems can only be representative of low levels of community organization. Care must also be taken to select representative organisms from each trophic level of the terrestrial ecosystem which the microcosm is to reflect. Also essential is adequate replication for data analysis to ascertain the degree of statistical variability between the experimental systems. Replication also permits the taking of "dynamic measurements" in such experiments, i.e., measurements taken at intermediate times other than at the "single-end state" (Eschenroeder and Tashima, in press). Since such intermediate nondestructive testing of the system is difficult additional replication could assist in obtaining such intermediate values by providing more systems and greater numbers of samples.

The diverse scientific papers on the use of microcosms have been oriented toward the environmental fate of pesticides, quite often in the aquatic environment. The paucity of data directly involving the use of these systems to study complex solid waste material in terrestrial environments is partially due to inadequate source characterization of the pollutants. Excellent reviews not directly related to microcosm usage are available, however, on various environmental issues, including uptake and accumulation phenomena of specific compounds related to coal conversion technology (Braunstein et al. 1977). For a broader overview also see the Proceedings of the National Conference on Health, Environmental Effects, and Control Technology of Energy Use (1976). In the specific area of microcosms, Witherspoon et al. (1976) provide an excellent review of their use in measuring transport of hazardous substances in the environment.

Research Needs

Research tasks needed are:

1) Further development and use of mathematical models coupled with the realistic use of artificial ecosystems (microcosms) to test such models. The most important environmental compartments to be included in a good model for each specific terrestrial ecosystem must be delineated. Experiments on factors such as photolysis, pollutant residence time and sorption characteristics and the affect of their addition to (or deletion from) the model will need to be ascertained.

2) Development of microcosms as valid "screening" agents to test the biological uptake and accumulation potential of various chemical fractions derived from complex pollutant mixtures. Specifically, microcosm studies that initially demonstrate which fractions have the greatest potential for uptake and accumulation at a simulated ecosystem level of organization could then be examined at other levels of biological organization. For example, particular species highly susceptible to accumulating such chemical fractions might then be studied for possible value as environmental indicators of mutagenicity, carcinogenicity and teratogenicity at the cellular level. Such studies would assist in the further development of criteria for inclusion in future monitoring programs.

3) Development of microcosm studies to investigate preferential organs of deposition and the amount of accumulation from particular fractions of organic pollutants. Special attention should be directed to determining seasonal patterns (if any) of pollutant uptake and/or accumulation. The possibility of such pollutants being translocated from one organ system to another over time may also need to be investigated.

4) Extensive investigations utilizing a microcosm approach to ascertain the extent to which abiotic factors, particularly soil pH, affects uptake of inorganic and organic pollutants. Some studies have shown that major food crops grown under even slightly acid soil conditions actively assimilate cadmium from applied solid waste pollutants such as sludge. Experiments with this contaminant and other inorganic and organic components of coal conversion solid wastes are needed to assess the affects of varying soil pH on pollutant uptake.

5) Microcosm experiments concentrating on being as reflective as possible in their choice of environmental factors representative of the geographic region where coal conversion facilities are to be located. Dominant species of both plants and animals from each region will have to be determined for inclusion in microcosm experiments. Research utilizing

such dominants and permutations of various pollutant constituents should be undertaken to determine the pattern and amount of such compounds metabolized by such species. Studies should also encompass major regional food crops directly consumed by man, as well as those agricultural products (e.g., beef, pork, fowl) eventually consumed by man.

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AMBIENT CHARACTERIZATION, MEASUREMENT AND MONITORING

The purpose of this panel report is to identify the measurement programs required to adequately delineate the types of concentrations of pollutants derived from coal conversion activities which may be released to the ambient environment (air, surface, water, groundwater). Both occupational (workplace) and public areas are addressed.

A basic recommendation is that all coal conversion demonstrations and all first-of-a-kind commercial coal conversion plants should be the subject of much more intensive occupational and environmental pollutant measurement programs than are currently planned. The panel feels that the measurement of unregulated environmental pollutants has been mostly neglected.

Occupational Surveillance

The identity and concentrations of pollutants to which workers are exposed in demonstration facilities is needed. Furthermore, ongoing surveillance measurements of hazardous emissions (e.g., Hydrogen, sulfide, carbon monoxide, hydrocarbons, toxic particles) are required. In addition to protecting workers, data from such programs will be useful in defining monitoring strategies for pollutants in the occupational environment of upcoming commercial plants.

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Pollutant Baseline, Characterization, and Monitoring Studies

Only a few baseline studies planned for initial demonstration plants relate to more than currently regulated pollutants. Without such baseline studies aimed at determining the ambient concentration of specific pollutants or classes of pollutants in the vicinity of a demonstration site, no environmental benchmark can be established against which to measure the eventual increases in ambient pollutants. Such baseline studies should be carefully designed to encompass those pollutants or pollutant classes which are of most concern to the protection of human health and the environment. Baseline monitoring of such pollutants as polycyclic hydrocarbons, carbonyl sulfide, and hydrogen cyanide is needed at least during a two year period before plant operation.

Ambient Characterization Studies

During initial plant operations, baseline studies should encompass a highly defined set of chemical species in order to determine ambient levels associated with the plant. Care should be taken to determine the buildup of trace substances in sediments and whether transformation processes are taking place in air or water which lead to more hazardous chemical compounds. The valence state of certain trace metals such as arsenic should also be determined. These intensive ambient characterization studies should take place during the first year or two of operation.

Ambient Monitoring

Based on the ambient characterization studies, a reduced number of pollutants should be monitored throughout the lifetime of a plant to detect any unforeseen trend which may develop. If present, such trends should then be examined in greater detail.

Specific Needs in the Ambient Measurement Area

The panel has also identified several more specific subsidiary needs pertaining to the more general measurements programs identified above. These include:

- Sampling needs centered on the preservation and extraction of organics compounds from ambient samples. The need to establish the validity of in situ process groundwater samples was also noted.
- The need for a comprehensive interlaboratory quality assurance program for all laboratories participating in the recommended monitoring programs was noted. This encompasses the need to develop standard reference calibration materials suited to ambient measurement methods.
- In the area of methods development, there is a need to develop techniques to measure non-chromatographable organic compounds, e.g., polar compounds.
- Methods are needed to measure the organic constituents of airborne particulate matter and such items as heterocyclics, carbonyl sulfide and hydrogen cyanide.

Finally, the need for certain special measurements studies was noted. These include:

- The determination of leachable substances from coal conversion wastes and their long-term monitoring.

- The long-term measurement of groundwater pollution from the in situ process.

- Ambient measurements of end use combustion of coal conversion products such as in vehicles, ships, or power plants not co-located with the conversion facility.

A summary of the problems, together with their respective priorities, level of effort and personnel resources is shown in Table I.

PANEL: AMBIENT CHARACTERIZATION, MEASUREMENT AND MONITORING

SUMMARY

PROBLEMS	PRIORITY	EFFORT	PERSON YEARS
1. Interlaboratory Quality Assurance Program for Ambient Monitoring	High	1.0M	11
2. Validity of Groundwater Samples collected from Gasification Sites	Medium	120K	2
3. Inadequate Ambient Sample Preservation Techniques	High	300K	5
4. Measurement of Non-Gas Chromatographable Organic Pollutants in Ambient Samples	High	2.5M	20
5. Inadequate Techniques to Extract Organics from Solid Samples	High	150K	3
6. Inadequate Ambient Baseline Studies	High	2.0M/per plant	25/per plant
7. Identify and Monitor Leachable Substances	High	1.0M	12
8. Ambient Air Releases from In Situ Burns	Medium	150K/site	2 per site
9. Inadequate Ambient Air Methods for Selected Compounds	High	300K	6
10. Inadequate methods for Sampling and Analysis of Organic Particulates from Synfuels	High	2.0M	20
11. Long Term Ambient Water Quality Monitoring of In Situ Coal Gasification Sites	Medium	500K/yr	6/year
12. Ambient Measurements of Pollutants from Combustion of Syncrude or Refined Syncrude	Medium	750K	7
13. Real Time and Long Term Ambient Water and Sediment Monitoring near Synfuel Sites	High	2.2M	35
14. Long Term Ambient Air Quality Monitoring of Selected Classes of Organic Compounds	High	750K	8
15. Industrial Hygiene Surveillance of Coal Conversion Plants	Very High	2.0M	20
16. Surveillance of Products Derived from Coal Conversion Processes	Medium	1.0M	10
17. Epidemiological Surveillance	Very High	1.5K	2.5
18. Develop Surveillance Equipment and Analytical Methodology for Benzene Solubles which are accurate, precise inexpensive.	Medium	1.0M	15
19. Industrial Hygiene Surveillance of Synfuel Commercial Plants	High	2.0M	40
20. Instrumentation for Specific Species Surveillance in Synfuel Plants	Medium	2.0M	20
21. Synfuel Product Surveillance	High	1.0M	15
22. Rapid Surveillance of the Relative Toxicity of Synfuel Liquids	Medium	3.0M	35

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 1

INTERLABORATORY QUALITY ASSURANCE PROGRAM FOR AMBIENT MONITORING

I. Problem Statement

Toxic organic compounds in the ambient environment surrounding coal conversion plants are potential health hazards. Ambient air, water, and sediment samples around these plants should be analyzed. The results of such analyses, however, cannot be adequately assessed without knowledge of the validity of the collected analytical data. Validity may be enhanced by: (1) the use of an adequate analytical methodology, and (2) the use of suitable quality assurance standards of Standard Reference Materials (SRM's).

II. Problem Discussion, Including Identified Subproblems

At present, SRM's for trace organic analyses are non-existent. The definition of an SRM requires the use of one of three modes of measurement to assure the accuracy of the value(s) of the SRM property(ies). These modes are: (1) definitive methods which are intrinsically free of systematic errors or those which are corrected for all such errors; (b) reference methods, or (c) two or more independently reliable methods. To date, the current state-of-the-art does not permit the certification of an SRM based on this definition. Reference and definitive methods do not exist. Several methods have recently been developed for analysis of several important classes of compounds such as polycyclic aromatic hydrocarbons (PAH), phenols and N-heterocyclics, but they have been validated.

In the interim, while SRM's are being developed and routine methods validated, reference materials or surrogate standards with real world concentrations should be made available to allow evaluation of an analyst's ability to perform quantitative analyses. All laboratories performing such analyses should be required to participate in this validation.

III. Priority of Problem: High

IV. Data and Information Requirements

Certain compounds should be certified as SRM and certain compounds and concentrations are desired to be used as surrogate standards.

V. Research Project(s)

(A) Development of definitive methods for trace organic analyses (for example, Isotope Dilution GC/MS procedures).

(B) Validation of recently developed methods for the analysis of complex oils. One such method is based on the isolation of fractions of such a mixture by high performance liquid chromatography (HPLC) followed by quantitative analysis by either HPLC, GC, or GC/MS with single ion monitoring. Such procedures might be evaluated by the analysis of real world samples with known amounts of a previously absent unknown spiked into the matrix.

(C) Development of HPLC methods for analysis of compounds that do not lend themselves to GC/MS analysis. Thus, there is a need for the further development of sensitive and selective HPLC detection systems.

(D) Development of reliable analytical procedures for classes of compounds.

VI. Expected Manpower

11 person years

Total funding: $1.0M

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 2

VALIDITY OF GROUNDWATER SAMPLES COLLECTED FROM IN SITU GASIFICATION SITES

I. Problem Statement

Studies of sampling techniques which assure the validity of groundwater samples collected at in situ coal gasification sites need to be conducted for the determination of concentrations of organic and trace element constituents.

II. Problem Discussion, Including Identified Subproblems

Groundwater samples will be collected downgradient from in situ coal gasification sites for research and monitoring purposes. The nature, level, and spatial position of expected organic and trace element contaminants may require special sampling techniques to provide valid samples. For example, can legitimate samples for organic analyses be obtained by the pumping from a standard observation well? Samples for trace element analysis may require plastic (PVC) cased wells which may be inappropriate for organic compound sampling.

III. Priority of Problem: Medium

IV. Data and Information Requirements

Identification and quantification of the organic compound and trace element contamination of groundwater samples collected by standard methods and conditions. Sampling techniques should include metal and plastic cased wells, the various types of well pumps commonly utilized, metal or plastic samplers, bailers, etc.

V. Relationship of Requirement to Stated Problem

Analysis of research results will determine if standard groundwater sampling techniques are appropriate for the collection and measurement of samples for organic and trace element constituents. These constituents are significant potential groundwater contaminants from in situ coal gasification operations. If necessary, specialized sampling techniques should be developed to identify these constituents.

VI. Availability/Adequacy of Existing Data--Identification of Data Gaps

Groundwater sampling and subsequent analysis for organics and trace elements have been conducted on a limited basis at both the Hanna and Hoe Creek in situ coal gasification test and development sites. The extent of replication or testing to assure that derived values are representative of those in the ambient groundwater environment has not been thoroughly investigated.

VII. Research Project(S)

An investigation will be performed relevant to the effects of sampling techniques on potential contamination of groundwater samples collected for analysis of organic compounds and trace elements. Research to be conducted will result in the comparison of various existing or postulated groundwater sampling procedures.

VIII. Relationship of Research Project to Data/Information Requirement

Research will identify the most appropriate sampling technique(s) for low levels of organic compounds or trace elements in groundwaters.

IX. Expected Manpower

2 person years

Total funding: $120 K

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 3

INADEQUATE AMBIENT SAMPLE PRESERVATION TECHNIQUES

I. Problem Statement

Analyses of the samples collected from coal conversion technologies are routinely performed at distant laboratories. As a result, procedures are needed to assure preservation of sample composition until analyses can be performed.

II. Problem Discussion, Including Identified Subproblems

If sample component decomposition or transformation occurs during sample storage, handling, or analysis, invalid data will be used to develop monitoring techniques, and to assess environmental and health effects.

III. Priority of Problem: High

IV. Data and Information Requirements

Techniques are needed which assure that the organic compounds detected after sample storage, handling, and analysis are those which were originally present in the sample and were not a result of sample processing. There is also a need to assure that the measured amount is indicative of the actual ambient concentration level.

V. Relationship of Requirement to Stated Problem

See above.

VI. Availability/Adequacy of Existing Data--Identification of Data Gaps

Available data are produced by the periodic analysis of a limited number of samples and address only the questions of changes which occur during sample storage. Techniques that are currently being used are not optimum and often produce spurious results. In addition, suspected problems have neither been confirmed or negated.

VII. Research Project(s)

A number of sample extracts should be analyzed periodically during the total storage time of several months. Some samples should be analyzed as soon as possible after collection, with replicate samples stored for varying periods and analyzed at varying intervals. A comparison of the results would indicate sample changes during the storage.

At collection times, samples should be spiked with a group of appropriate marker compounds to develop information relating to those compound classes which tend to disappear, to decompose, to transform, or to remain stable with time. Causative factors should be investigated to permit the selection of appropriate techniques depending on the type of sample to be analyzed.

VIII. Relationship of Research Project to Data/Information Requirement

The research project would focus on the analysis of coal conversion samples and would also advance the state-of-the art but should not be expected to answer all questions concerning sample preservation.

IV. Expected Manpower:

5 person years

Total funding: $300K

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 4

MEASUREMENT OF NON-GAS CHROMATOGRAPHABLE ORGANIC POLLUTANTS IN AMBIENT SAMPLES

I. Problem Statement

Potentially hazardous organic compounds emitted from coal conversion activities cannot all be identified and measured by currently available techniques. These techniques involve computerized gas chromatography-mass spectrometry systems.

II. Problem Discussion, Including Identified Subproblems

Well-developed analytical methods exist for the analysis of gas chromatographable compounds, but sample components that do not elute from a gas chromatograph remain essentially unknown. To assure the adequate characterization of non-gas chromatographable organic compounds, which are potentially hazardous and might require monitoring in ambient air and water, analytical techniques need to be developed.

III. Priority of Problem: High

IV. Availability/Adequacy of Existing Data--Identification of Data Gaps

Well-developed techniques exist for the analysis of gas chromatographable compounds, but sample components that do not elute from a gas chromatograph remain essentially unknown. Because the non-gas chromatographable components may constitute 50 to 80 percent of the total organic carbon content of a sample, a significant portion remains unidentified. Recent work with liquid chromatography indicates that more effort should be expended with the technique. Systems combining liquid chromatography (LC) and mass spectrometry appear to have the greatest probability of success, but detectors for LC eluants need further development.

V. Research Project(s)

Improved liquid chromatograph detectors that need further investigation include mass spectrometry, amperometric techniques, atomic absorption, and plasma emission spectrometry.

VI. Expected Manpower

20 person years

Total: Funding $2.5M

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 5

INADEQUATE TECHNIQUES TO EXTRACT ORGANICS FROM SOLID SAMPLES

I. Problem Statement

Procedures to extract organic components from solid samples (including sludge, fugitive dust, sediments, and particulates) need to be validated.

II. Problem Discussion, Including Identified Subproblems

Solid samples are potential carriers and emitters of hazardous organic compounds within the ambient environment. As a result, such substances may require monitoring and need delineation through appropriate extraction procedures.

III. Priority of Problem: High

IV. Data and Information Requirements

Development and demonstration of adequate extraction techniques, which may vary with sample type.

V. Availability/Adequacy of Existing Data--Identification of Data Gaps

Existing techniques have not been validated, and no consensus exists as to the best techniques. Incomplete recovery is a common problem, and chemical transformation may occur during extraction procedures, especially for those techniques which involve the heating of the samples. Loss of volatile components frequently occurs during sample handling and preparation.

VI. Research Project(s)

A comparison should be made of present extraction techniques (such as Soxhlet and ultrasonication) to determine optimum conditions and results.

An investigation should be made of new or modified extraction techniques to improve recovery and present loss of volatile organics.

There should be a demonstration of the validity of recommended techniques and a determination of their limitations.

There should be an assessment of specific techniques for different sample types and components.

VII. Expected Manpower

3 person years

Total funding: $150K

PANEL: Ambient Measuring and Monitoring

PROBLEM NUMBER: 6

INADEQUATE AMBIENT BASELINE STUDIES

I. Problem Statement

All coal conversion demonstrations and initial commercial plants may emit a variety of organics, trace elements, and inorganics to air and water in the vicinity of the plant. Sophisticated ambient baseline monitoring of unregulated pollutants is required to provide a benchmark for the impacts of these initial plants on local media. If such ambient baseline studies are not planned and funded, the opportunity to understand the relevancy of impacts will be lost.

II. Problem Discussion, Including Identified Subproblems

Before obtaining an adequate understanding of the effects of specific pollutants in the ambient environment, it is necessary to establish the concentrations of specific pollutants in air and water due to a given plant type over a period of time. In order to relate the increase in ambient levels associated with plant operation, background levels or baseline reference benchmarks must be established.

An important aspect of this problem is to establish the minimum set of pollutants or classes of pollutants which must be monitored to allow for an adequate margin for the protection of human health. A further aspect of this problem is the degree of definition which is adequate (e.g., total organic carbon, PAH, etc.).

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 6 (Concluded)

III. Priority of Problem: High

IV. Expected Manpower

25 person years per demonstration plant

Total funding: $2M per plant

PANEL: **Ambient Measuring and Monitoring**

PROBLEM NUMBER: 7

IDENTIFY AND MONITOR LEACHABLE SUBSTANCES

I. Problem Statement

The total amount of solid residue from a modern coal conversion facility will be from 15-40 percent of the total coal mass input. These residues, including ashes, chars, sludges, and slags will be disposed of in landfill sites, mined areas, or held on ash sludge ponds. Ground and surface waters, soils, and aerosols may subsequently contain leached elements or compounds which are ecologically or biologically detrimental.

II. Problem Discussion, Including Identified Subproblems

Material will be leached from the solid waste as a function of a number of parameters, including varying operating plant conditions, temperatures of conversion and processing, and disposal environments. Once leached, bioavailability may be dependent on the valence state, the nature of complex formed, solubility, or physical absorption processes. Leachability must be studied as a function of these parameters. Studies of compounds released may require refinement of available techniques for organometallic analyses, trace element speciation, and the analyses of polar organic compounds at extremely low concentration levels. Analysis of the leachate is necessary to identify the materials which should be monitored routinely or continuously.

III. Priority of Problem: High

IV. Data and Information Requirements

Identification of leachates which may cause environmental concern will require information on expected leaching rates, rates of transformation of organics and inorganics, identification of leachate species, and determination of their absolute concentrations. Information on site specific disposal plans will be necessary in order to evaluate the effect of local groundwater conditions. Data on the applicability of new instrumental techniques for organametallic complexes are required. Information on methods for polar organic sensitivity is also needed.

V. Availability/Adequacy of Existing Data--Identification of Data Gaps

Leaching studies or Lurgi gasifier ash have shown that under certain pH conditions, water standards for B, Ca, Cd, K, Mn, NH_4, Pb and SO, will be exceeded. Information from other studies is limited. Methods for organometallic analyses are limited to a few specific procedures such as for carbonyls and biologically important complexes. Speciation of trace elements is adequate for some inorganics (such as Ca, Fe, Al, Cd, etc.) by polargraphic techniques.

VI. Research Project(s)

Identify components of leachates and their transformation products from spent materials under a variety of conditions which mimic actual field conditions.

Investigate and compare methods for organometallic analysis including LC with AA, amperometric, and XRF detection.

Develop an improved LC/MS system which does not cause pyrolysis of the component being analyzed and which is sensitive at the ppb or ppt level.

VII. Expected Manpower

12 person years

Total funding: $1M

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 8

AMBIENT AIR RELEASES FROM IN SITU BURNS

I. Problem Statement

Production flow Btu gas from an in situ coal process will result in the production of potentially toxic materials such as aromatic hydrocarbons, heterocyclics, and particulate matter. Continuous monitoring systems must be available to give early identification of effluent release above the allowed limits.

II. Problem Discussion, Including Identified Subproblems

During the controlled burn of a coal seam, problems in seam collapse, earth subsidence, or permeation of the seam by an outside air source may result in an uncontrolled burn condition. Emissions from such a burn may be released to the atmosphere through inspection holes, test drill holes, instrumentation access sites, or through natural vent holes. The resulting pollutants may include CO, SO_x, NO_x, H_2S, HCN, Hg, hydrocarbons, and particulates. Even during a well-controlled burn, emissions may accidentally be released through natural or man-made penetrations of the burn region. Methods of monitoring for such pollutant releases must be in place.

III. Priority of Problem: Medium

IV. Data and Information Requirements

Background ambient levels for potential pollutants must be measured to establish threshold levels. It is expected that an indication of an increase in CO, H_2S, NO and HC levels will infer a commensurate increase in polycyclic and heterocyclic hydrocarbons.

V. Availability/Adequacy of Existing Data--Identification of Data Gaps

In situ burns of commercial size have not been attempted; hence, insufficient data exists in the anticipated effluent levels.

VI. Research Project(s)

Determine background levels of criteria pollutants. A preliminary hydrocarbon screen of ambient gases and particles should be performed.

Measure particulates (trace elements and extractable organics) and screen organic releases during a commercial scale burn.

VII. Relationship of Research Project to Data/Information Requirement

Information gained from the research will provide the assessment required to select ambient monitors to be required near commercial in situ burn sites.

VIII. Expected Manpower

2 person years per site

Total funding per site: $150K

PANEL: **Ambient Measuring and Monitoring**

PROBLEM NUMBER: 9

INADEQUATE AMBIENT AIR METHODS FOR SELECTED COMPOUNDS

I. Problem Statement

The methodologies for the collection and analysis of the criteria pollutants, such as CO, SO_x, NO_x and TSP, that will be emitted from synthetic fuel processes, appear to be adequate. Methodologies should be developed for the collection and analysis of other environmentally significant compounds (such as aromatic amines, and hydrogen cyanide) that may be emitted from synfuel plants.

II. Problem Discussion, Including Identified Subproblems

Aromatic amines may be present at synfuel sites, particularly if an amine process is used for acid gas removal. The amines can then react with NO_x from flares, furnaces, and oxiders to form nitrosamines, which are extremely carcinogenic. Hydrogen cyanide is also a highly toxic material that may be present as a fugitive emission in synfuel plants.

III. Priority of Problem: High

IV. Availability/Adequacy of Existing Data--Identification of Data Gaps

A technique is being developed at the University of Pittsburgh for the analysis of aromatic amines. Presently, there are CG-chemilunescense methods available for the analyses of nitrosamines.

V. Research Project(s)

Develop techniques for the collection and analysis of aromatic amines either by ion chromatography or high pressure liquid chromatography.

Develop ion chromatographic method for the analysis of HCN.

VI. Expected Manpower

6 person years

Total funding: $300K

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 10

INADEQUATE METHODS FOR SAMPLING AND ANALYSIS OF ORGANIC PARTICULATES FROM SYNFUELS

I. Problem Statement

Airborne particles, as well as other emissions from coal conversion processes, will contain more hazardous compounds than particulate matter emitted from coal-fired power plants.

II. Problem Discussion, Including Identified Subproblems

The analysis of these hazardous pollutants in coal conversion fuels is a difficult analytical problem. For example, the PAH's and aza-arenes in aerosol tars, which are known to be potent human carcinogens, are present in a complex matrix of hundreds of these organic compounds. Many of these compounds occur in low concentrations beyond the sensitivity of current techniques and therefore require a pre-concentration step. Development of more selective and sensitive detection systems for high performance liquid chromatography (HPLC) would aid in the objectives of specific compound identification.

Improved LC/MS interfaces are needed.

III. Priority of Problem: High

IV. Availability/Adequacy of Existing Data--Identification of Data Gaps

LC/MS is not commercially available but the availability needs to be improved. Most of the current chromatographic detection methods do not permit specific compound detection. More selective and sensitive detectors would aid in qualitative and quantitative analyses.

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 10 (Concluded)

V. Research Project(s)

Develop LC/MS.

Develop nitrogen and sulfur detectors.

Develop specific electrochemical LC detectors

Develop GC detectors.

VI. Expected Manpower

20 person years

Total funding: $2.0M

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 11

LONG TERM AMBIENT WATER QUALITY MONITORING OF IN SITU COAL GASIFICATION SITES

I. Problem Statement

There is a necessity for the long-term monitoring of water quality and the physical effects of in situ coal gasification on the groundwater environment.

II. Problem Discussion, Including Identified Subproblems

In situ coal gasification may take place within close proximity to aquifers. During gasification, alteration of the physical characteristics of an aquifer or dry subsurface zone may occur. Changes in such parameters as hydraulic conductivity, porosity, etc., are likely. Such changes could affect groundwater movement in the subsurface. The potential for physical changes should be determined, the type identified, characterized as transient or permanent, and techniques for monitoring identified.

Downgradient water quality effects are an associated problem. These may occur due both to contamination from leaching of the gasified material and/or to changes in the hydrogeologic regime induced by physical alterations in the subsurface (i.e., vertical movement of waters through previously impermeable confining beds). The temporal and spatial extent of physical water quality effects of in situ coal gasification have to be defined. Only then can the level and type of monitoring required be assessed.

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 11 (Continued)

III. Priority of Problem: Medium

IV. Data and Information Requirements

(a) Pre-burn and post-burn groundwater quality data on selected constituents (organics, inorganics, trace elements) both up and downgradient from a representative in situ coal gasification site over some extended period of time.

(b) Determination of aquifer characteristics both pre and post-burn at gasification sites where (1) the coal seam is a major aquifer, and (2) the coal seam overlies or underlies a major aquifer.

V. Relationship of Requirement to Stated Probelm

Information collected will provide the background to assess the need for the long-term monitoring of in situ coal gasification sites and the potential for significant downgradient flow and quality effects. If a need for long-term monitoring is demonstrated (leaching is a long-term feature or physical changes to the aquifer are extensive) the information developed may provide guidance in design and operation of an appropriate monitoring network.

VI. Availability/Adequacy of Existing Data--Identification of Data Gaps

Data on pre, during, and post-burn groundwater quality and hydrogeologic parameters has been collected at the Hoe Creek and Hanna in situ coal gasification test sites. These data are relatively short-term and would not have the information required to estimate potential long-term effects.

PANEL: **Ambient Measuring and Monitoring**

PROBLEM NUMBER: 11 (Concluded)

VII. Research Project(s)

Design of monitoring system for assessing groundwater quality impacts downgradient from in situ gasification sites.

VIII. Relationship of Research Project to Data/Information Requirement

Provide the monitoring system (sampling/analysis) applicable to in situ gasification sites both during and subsequent (long term) to active coal gasification activities.

IX. Expected Manpower

6 person years

Total funding: $500K

PANEL: Ambient Measuring and Monitoring

PROBLEM NUMBER: 12

AMBIENT MEASUREMENTS OF POLLUTANTS FROM COMBUSTION OF SYNCRUDE OR REFINED SYNCRUDE

I. Problem Statement

There exists a need for specialized ambient monitoring in the vicinity of facilities utilizing coal derived synthetic liquid fuels.

II. Problem Discussion, Including Identified Subproblems

The products of coal liquification have been shown to contain a greater variety of potentially hazardous organic compounds such as phenols, aerosols, polynuclear aromatics, and trace elements than in petroleum-based oil products. The increased levels of organic compounds and trace elements found in coal-derived liquid fuels result from the composition of the source coal and the metal catalysts used in the conversion processes. Combustion of these products may, therefore, require a more vigorous monitoring system than would be applicable to the combustion of petroleum derived products.

III. Priority of Problem: Medium

Identification and quantification of organic compounds and trace elements released during combustion of coal derived liquid fuels.

V. Relationship of Requirement to Stated Problem

Provide information upon which the decision can be based as to the level of monitoring required of facilities utilizing coal-derived liquid fuels.

PANEL: **Ambient Measuring**
and Monitoring

PROBLEM NUMBER: 12 (Concluded)

VI. Availability/Adequacy of Existing Data--Identification of Data Gaps

A limited quantitative characterization of emissions from coal derived synthetic liquid fuel utilization has been conducted. The presence of the greater levels of deleterious components in liquid synfuels is documented.

VII. Research Project(s)

Characterize emissions from the combustion of coal-derived synthetic liquid fuels.

VIII. Relationship of Research Project to Data/Information Requirement

This project will identify and quantify the range of organic, trace element, and other compounds in combustion emissions.

IX. Expected Manpower

7 person years

Total funding: $750K

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 13

REAL TIME AND LONG-TERM AMBIENT WATER AND SEDIMENT MONITORING NEAR SYNFUEL SITES

I. Problem Statement

There is a great need for both real time and long-term ambient measurement of potentially hazardous pollutants associated with coal conversion technologies. Such measurements are particularly important for PAH's, aromatic amines, phenols, and certain other criteria pollutants.

II. Problem Discussion, Including Identified Subproblems

The exposure of individuals and the environs to toxic pollutants emitted from coal conversion facilities must be measured by both real time and continuous long-term monitoring. Real time measurement for detection of catastrophic exposure levels is needed. Continuous long-term monitoring for measurement of the build up of various pollutants above baseline levels is also essential. A quality control program with well-defined guidelines needs to be developed and formulated in order to make such data meaningful. Precise reference methods should be adopted.

III. Priority of Problem: High

IV. Data and Information Requirements

(a) There is a need to develop information about the specific organic compounds present in untreated effluents from coal conversion plants. There is also a need to develop a list of specific compounds that require monitoring (i.e., major constituents and minor constituents known to be toxic).

(b) Methods with a high degree of precision and known accuracy to implement monitoring systems should be developed.

V. Availability/Adequacy of Existing Data--Identification of Data Gaps

Characterization of effluents from coal conversion plants is presently being done. From the information obtained, a list of compounds to be monitored should be formulated. Methods exist (GC, HPLC) that allow accurate quantitative analysis of pollutants when isolated from the matrix in appropriate solvents. While there are several published methodologies for total sample analysis (matrix--chromotographic analyses) none of them have been validated for the various matrices involved in coal conversion technologies.

VI. Research Project(s)

Develop monitoring techniques (sampling and measurement) with the sensitivity, accuracy, and precision necessary to detect small changes in pollutant levels.

Compare various sampling, extraction, and measurement methods in terms of sensitivity, accuracy, and precision. Sufficient information should be derived to determine reference methods for various classes of pollutants in various matrices.

VII. Expected Manpower

35 person years

Total funding: $2.2M

PANEL: Ambient Measuring
and Monitoring

PROBLEM NUMBER: 14

LONG-TERM AMBIENT AIR QUALITY MONITORING OF SELECTED CLASSES OF ORGANIC COMPOUNDS

I. Problem Statement

Long-term monitoring capabilities for certain pollutants such as total carbon, total organic carbon and elemental carbon, are needed. Analyses based on classes of compounds are important as possible parameters in ambient air measurement.

II. Problem Discussion, Including Identified Subproblems

There are many organic compounds that are found during the monitoring of synfuel processes. Current analytical methods for organic compounds have focused on relatively non-polar types. For example, polar organics occurring in polluted atmospheres and groundwaters are important because of their potential biological significance. Methods for analysis of organic compound classes need to be developed.

III. Priority of Problem: High

IV. Availability/Adequacy of Existing Data--Identification of Data Gaps

Relevant research is ongoing at the University of Arizona for total carbon, total elemental carbon, and the different classes of organics. However, additional funding is needed to continue research into these areas.

V. Research Project(s)

Develop methodology and/or instrumentation for the analysis of total carbon, total organic carbon, and elemental carbon.

Develop methods based on classes of organic compounds such as polar organic compounds.

VI. Expected Manpower

8 person years

Total funding: $750K

PANEL: Ambient Measuring
and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 15

INDUSTRIAL HYGIENE SURVEILLANCE OF COAL CONVERSION PLANTS

I. Problem Statement

Worker occupational exposures in existing (and future) pilot scale or demonstration scale facilities have not been determined. Only the Gulf Ft. Lewis (SRC) pilot facility has begun industrial hygiene characterization, and it is only for one process.

II. Problem Discussion Including Identified Subproblems

Since coal gasification (high, medium low Btu, high temperature) processes and liquefaction processes produce toxic and hazardous gases, liquids, and solids, worker exposures must be determined. This must be done for existing and planned facilities in order to:

(1) protect the workers

(2) provide data, where appropriate, that can be applied to larger or commercial scale facilities

It is suggested that this type of work be done at operations larger than the pilot plant (large PDU) particularly for engineering control technology or for scaling purposes. This is because the equipment and operating environment loses all relationship to more complex commercial plants.

III. Priority of Problem: Very High

PANEL: Ambient Measuring and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 15 Continued

IV. Data and Information Requirements

An identification (qualitative, quantitative) of species present in worker environments must be made. These species must be prioritized in terms of their importance in occupational safety and health areas.

Sampling techniques, equipment, collection media, sample preservation, and analytical protocols need to be reviewed and revised as required by these special sampling circumstances.

Data needs to be evaluated and extrapolated where possible for demonstration and commercial facilities.

V. Relationship of Requirement to Stated Problem

In order to determine worker exposure, species present in worker environments must be determined.

VI. Availability/Adequacy of Existing Data - Identification of Data Gaps

Little if any data exists on worker exposure in commercial coal conversion facilities. Some NIOSH and DOE programs have just begun to obtain data in this area.

PANEL: **Ambient Measuring and Monitoring**

SUBPANEL: **Occupational Surveillance**

PROBLEM NUMBER: 15 (Concluded)

VII. Research Project(s)

Industrial hygiene characterization of coal liquefaction pilot plants.

Industrial hygiene characterization of coal gasification pilot plants.

Determination of worker exposure at the pilot plants.

Extrapolation to the commercial plant worker environment.

VIII. Relationship of Research Project to Data/Information Requirement

The data will be used for two purposes--to protect the pilot plant worker and to extrapolate to the occupational environment expected to be found at the demonstration-commercial level. This extrapolation will provide the synfuel plant developer with an insight into real occupational and environment problems. This insight will help the developer to design a safer plant at less cost than would occur if the engineering controls had to be retrofitted. It will also help to prevent needless exposure of workers to emissions that might otherwise be unexpected.

IX. Expected Personpower

20 person years.

Total funding: $2.0M

PANEL: Ambient Measuring
and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 16

SURVEILLANCE OF PRODUCTS DERIVED FROM COAL CONVERSION PROCESSES

I. Problem Statement

Products and product intermediates processed from liquids derived from coal conversion processes may be toxic. The combustion of liquid fuels and of certain low-BTU gases may prove to be difficult and may pose problems to occupational and ambient atmospheres.

II. Discussion of Problem Including Subproblems Identified

Aromatic materials may contain toxic quantities of carcinogenic steroids which may be hazardous to human health. Russian data indicate that gasoline from coal produces skin rashes while gasoline from petroleum does not produce a rash under similar circumstances. This would indicate that not only are the coal derived liquids hazardous, but that intermediate and finished products derived from coal conversion products may also be hazardous.

The combustion of aromatic liquids is difficult and often produces clouds of smoke. During the test of Project COED liquid product on the USS Johnston in 1974, dense clouds of black smoke were observed. During the burn test of SRC I product in 1977 it was reported that the stock gas contained very fine particles which were not stopped by electrostatic precipitators or by correctional baghouse filters.

PANEL: **Ambient Measuring and Monitoring**

SUBPANEL: **Occupational Surveillance**

PROBLEM NUMBER: 16 (Continued)

III. Priority of Problem: Medium

IV. Data and Information Requirements

Data on the toxicity of products and product intermediates of materials derived from synfuel liquids are needed.

The composition of end products from the combustion of low BTU gas under a variety of conditions, plus the composition and toxicity of the combustion products from burning synfuel (liquids, SRC) under a full range of combustion conditions are also needed.

V. Relationship of Requirement to Stated Problem

This data will determine the correct requirement for processing and combusting synfuel products and the intermediate and refined materials made from synfuel liquids. It will also enable coal processors to take proper occupational health precautions.

VI. Availability/Adequacy of Existing Data - Identification of Data Gaps

Some data are available but are inadquate.

VII. Expected Personpower:

Total funding: $1.0M

PANEL: Ambient Measuring and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 17

EPIDEMIOLOGICAL SURVEILLANCE

I. Problem Statement

Coal tars (synfuel products) are carcinogenic. There may be 500,000 people involved in coal tar production by 2000 A.D. At present there is no epidemiological information concerning the effects of coal tar on humans.

II. Problem Discussion including Identified Subproblems

Coal tars have been identified as being responsible for systemic and skin cancers in coke oven workers. Also, it has been demonstrated that synfuel liquids are carcinogenic. Cancers and pre-cancerous lesions were formed on Insitute, W. VA. Pilot Plant (Bergius process) workers (51 incidents for 359 workers in over five years). Similar effects have not been observed at Consol Coal R&D Lab., IGT, Perc, Merc, or Sasol. The study of Sexton workers (50 with lesions) showed no systemic cancer.

The need for a retrospective and prospective epidemiology study of synfuel workers is badly needed to define the extent of the coal tar problem.

III. Priority of Problem: Very high.

PANEL: Ambient Measuring and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 17 (Concluded)

IV. Data and Information Requirements

Epidemiological data need to be collected from all unconfounded coal conversion projects in the U. S. Retrospective data should be sought from European and South African operations if possible.

A prospective epidemiological program must be initiated in all operating vs. pilot plants, coal research facilities, and upcoming demonstration and commercial plants. These studies should include full medical records and tests.

V. Relationship of Requirement to Stated Problem

These epidemilogical data should define the extent of the carcinogenic problem and will help to document the occupational standards required.

VI. Availability/Adequacy of Existing Data - Identification of Data Gaps

Little to none including WWII German plants.

VII. Expected Personpower:

2.5 person years

Total funding: $1.5K

PANEL: Ambient Measuring
and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 18

DEVELOP SURVEILLANCE EQUIPMENT AND ANALYTICAL METHODOLOGIES FOR BENZENE SOLUBLES WHICH ARE ACCURATE, PRECISE, AND INEXPENSIVE

I. Problem Statement

OSHA regulations call for a limit to coal tar benzene cyclohexane soluble materials. There is no instrument available for giving real time exposure rates to workers. Two types of instrumentation must be developed: The first would measure an area sample, and the second would measure a personal sample. Both must be effective and sufficiently low cost that all synfuel plant operators can and will buy them.

II. Problem Discussion including Identified Subproblems

OSHA regulations limit exposure to benzene soluble coal tars to 0.2 ppm. Present equipment for sampling these materials and analytical techniques for determining concentration are slow, inaccurate, and imprecise. The error of the analytical technique is greater than the standard limit. It is impossible to tell when a worker is overexposed to coal tars. In small plants if the exposure measurements are made at all, samples must be sent to outside laboratories. Information is delayed by weeks. Further, the accuracy of available sampling equipment is low and cost is high. Personal samplers are totally inadequate.

It is estimated that low Btu gasifiers will proliferate the countryside. These will be located near urban areas and collectively will employ as many people as the large plants. It is postulated that these low pressure units will "leak" much more than the high - BTU operations.

PANEL: **Ambient Measuring and Monitoring**

SUBPANEL: **Occupational Surveillance**

PROBLEM NUMBER: 18 (Continued)

III. Priority of Problem: Medium

IV. Data and Information Requirements

There is a need for accurate real time, low cost area samplers for benzene solubles.

Also needed is an accurate low cost, simple personal sampler.

A vastly improved methodology for analyzing benzene solubles and tars is also necessary.

V. Relationship of Requirement to Stated Problem

Accurate real time instruments and precise analytical methodology will drastically reduce worker exposure to coal derived benzene soluble materials. Inexpensive equipment will mean that all synfuel operators can afford to buy, install, and use the equipment. Expensive equipment will not be purchased at the level of the low-Btu small use gasifier.

VI. Availability/Adequacy of Existing Data - Identification of Data Gaps

One new instrument is being developed at ORNL. However, in its present stage of development this instrument is too expensive for widespread marketing.

VII. Research Project(s)

Design an accurate real time low cost area sampler for benzene solubles.

Design a low cost simple personal sampler for benzene solubles.

Design and implement an instrument suitable for analyzing benzene solubles.

PANEL: **Ambient Measuring**
and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 18 (Concluded)

VIII: Relationship of Research Project to Data/Information Requirement

IX. Expected Personpower:

15 person years.

Total funding: $1.0M

PANEL: Ambient Measuring
and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 19

INDUSTRIAL HYGIENE SURVEILLANCE OF SYNFUEL COMMERCIAL PLANTS

I. Problem Statement

Occupational exposures in existing commercial coal conversion facilities have not been determined. Plans to determine occupational exposures in the future commercial facilities have not been defined nor has sufficient work been performed to project potential exposures.

II. Problem Discussion, Including Identified Subproblems

Since coal gasification (high, medium low Btu, high temperature) processes and liquefaction processes produce toxic and hazardous gases, liquids, and solids, worker exposures must be determined. This determination must be made for existing and planned facilities.

III. Priority of Problem: High

IV. Data and Information Requirements

An identification (qualitative, quantitative) of species present in worker environment must be made. These species must be prioritized in terms of their importance in the occupational safety and health area. Data should be utilized to strengthen methodology for extrapolating occupational safety and health information from pilot sized facilities.

V. Relationship of Requirement to Stated Problem

In order to determine worker exposure, species present in worker environments must be determined.

In order to make use of the data extrapolation techniques utilized at the pilot plant level, technologies must be confirmed or revised.

VI. Research Project(s)

Industrial hygiene characterization of coal conversion demonstration and commercial coal conversion processes.

VII. Relationship of Research Project to Data/Information Requirement

Direct

VII. Expected Manpower

40 person years

Total funding: $2.0M

PANEL: Ambient Measuring
and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 20

INSTRUMENTATION FOR SPECIFIC SPECIES SURVEILLANCE IN SYNFUEL PLANTS

I. Problem Statement

Improved instruments are needed for short-term sampling and longer term monitoring of the worker environments in coal conversion facilities for specific species which are regulated by OSHA or recommended for regulation by NIOSH.

II. Problem Discussion, Including Identified Subproblems

See document being prepared by Brookhaven National Laboraotires (Mort Lipman, et al.) for the Department of Energy.

III. Priority of Problem: Medium

IV. Data and Information Requirements

An identification (qualitative, quantitative) of species present in worker environments must be made. These species must be prioritized in terms of importance to occupational safety and health.

V. Relationship of Requirement to Stated Problem

Once the species are identified and prioritized, improved or specific instruments can be developed and built. With instruments then available, improved and more detailed personal sampling and area monitoring can be performed to develop a data base concerning worker occupational environments.

PANEL: **Ambient Measuring and Monitoring**

SUBPANEL: **Occupational Surveillance**

PROBLEM NUMBER: 20 (Concluded)

VI. Availability/Adequacy of Existing Data--Identification of Data Gaps

NIOSH, DOE, and several private companies have programs underway to characterize worker occupational environments in some existing coal conversion facilities. Work is just beginning and no significant or comprehensive data base exists.

VII. Research Project(s)

Identify (qualitative and quantative) species of interest and concern to occupational safety and health.

Identify deficiency in current instrumentation.

Develop personal sampling and area monitoring instrumentation that will:

(a) provide direct readings
(b) measure gas compositions
(c) measure particle sizing and amounts
(d) measure noise
(e) measure heat
(f) be computer adaptable
(g) be small and inexpensive

VIII. Expected Manpower

20 person years

Total funding: $2.0M

PANEL: Ambient Measuring
and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 21

SYNFUEL PRODUCT SURVEILLANCE

I. Problem Statement

Fugitive emissions form a primary source of occupational exposure. The source of these emissions is from inadequately controlled plant equipment.

II. Problem Discussion, Including Identified Subproblems

Worker exposure to hazardous materials can cause health problems throughout worker's lives. For operators--pilot plants, demonstration and commercial--a great deal of exposure comes from fugitive emissions emanating from equipment. This equipment includes valves, instruments, pump seals, flanges, etc. Equipment used in coal conversion plants is not built to meet the harsh process conditions found there. Consequently, failures are frequent. Better equipment is needed to reduce mechanical failure and worker exposure.

III. Priority of Problem: High

IV. Data and Information Requirements

Data are required on the exact nature of the equipment failure which leads to worker exposure. Data are required on the methods used to make this equipment function in the pilot plant environment. Data are needed on failures as well as successes. Data collected from an operating pilot, which is the only place it exists in available form, can then be synthesized and used to define the real equipment problem needs for demonstration and commercial plants.

PANEL: Ambient Measuring and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 21 (Concluded)

V. Relationship of Requirement to Stated Problem

Data will help define the source of this problem. These data will also help to define or bound the problem solution and will form the basis for improved control technology recommendations.

VI. Availability/Adequacy of Existing Data--Identification of Data Gaps

The few data collected relevant to this area are not useful for comparison, analysis, or integration.

VII. Research Project(s)

Using existing pilot plants and related commercial facilities, a control technology study of coal conversion facilities including gasification and liquefaction should be conducted. The net result will be specific control equipment recommendations and recommendation for the development of new equipment.

VIII. Relationship of Research Project to Data/Information Requirement

Direct.

IX. Expected Manpower

15 person years

Total funding: $1.0M

PANEL: Ambient Measuring
and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 22

RAPID SURVEILLANCE OF THE RELATIVE TOXICITY OF SYNFUEL LIQUIDS

I. Problem Statement

The relative toxicity of various coal tars may change with varying process conditions.

II. Problem Discussion, Including Identified Subproblems

Coal tars are proven carcinogens. Different fractions of coal tars from various sources show different toxic intensity. It may be assumed that coal tar fractions from different coals and coal tars from different conversion processes, (fixed bed gasification, synthane, hygas, solvent liquefaction, catalytic liquefaction, hydrocarbonization, pyrolysis) will have different molecular configurations and therefore different reactive toxicity.

III. Priority of Problem: Medium

IV. Data and Information Requirements

Data are needed on the relative toxicity of the various fractions. Such data should be obtained by a rapid, inexpensive screening methodology (for example, a modified Ames Test).

Data should be obtained from bench scale, PDU, or from pilot plant liquids. Such liquids should be fractionated by boiling point, species, and molecular weight.

PANEL: Ambient Measuring
and Monitoring

SUBPANEL: Occupational Surveillance

PROBLEM NUMBER: 22 (Concluded

V. Relationship of Requirement to Stated Problem

Such data will give insight into the effect of processing on the toxicity of coal tars. It is to be anticipated that certain types of processing or process parameters may reduce the toxicity of the tar fractions, thus reducing the risk of worker and community exposure.

VI. Availability/Adequacy of Existing Data--Identification of Data Gaps

The only data developed to date have been generated at ORNL on coke over tars vs synthetic tars. These data clearly demonstrate differential toxicity.

VII. Research Project(s)

Obtain total tar fractions from a coal conversion facility at different operating or combination of operating parameters. Fractionate each fraction in the same source as described above. Determine relative toxicity. Reheat for other coal conversion facilities. Integrate data.

VIII. Relationship of Research Project to Data/Information Requirement

Direct.

IX. Expected Manpower

35 person years

Total funding: $3.0M

SOURCE CHARACTERIZATION

Report of Findings:

SOURCE, OCCUPATIONAL AND AMBIENT CHARACTERIZATION, MEASUREMENT AND MONITORING IN COAL GASIFICATION AND LIQUEFACTION PROCESSING

to

Workshop on the Health and Environmental
Effects of Coal Gasification and Liquefaction Technologies

Sponsored by

The Federal Interagency Committee on the
Health and Environmental Effects of Energy Technologies

February 7, 1979

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INTRODUCTION

Source characterization, measurement and monitoring constitutes the reference point from which effective assessment of the health and environmental effects of coal gasification and liquefaction processing must proceed. However, as became apparent in the first days of the workshop, a number of complicated factors currently limit the availability of process-specific commercially scaled effluent data required for these assessments. It is toward these factors that the Source Characterization panel directed its attention.

Evolution of Source Characterization in Gasification and Liquefaction Processing

Lack of a commercially based gasification and liquefaction industry and its attendant reservoir of experience has had a major impact on the evolution of techniques, protocols, strategy, and data for source characterization. Resources for samples of effluent material, particularly with respect to medium- and high-Btu processes, have been and continue to be small scale. Such systems typically operate only intermittently and over a wide range of conditions, while producing relatively small quantities of raw untreated effluent. Techniques available for source characterization in commercially established industries have often been found wanting. New techniques have had to be developed both to extend source characterization to unconventional parameters and to accommodate a wide range of vagaries associated either with the basic technology or with its scale of experimental development.

The response of the source characterization community to factors such as those above has resulted in a distribution of efforts across a set of distinct but complementary activity areas. Table I summarizes these activities. Sample characterization and more recently process characterization presently constitute the bulk of the efforts; bioassay techniques are increasingly providing a complement to traditional chemical measurement techniques. As individual technologies advance toward commercialization, effluent treatment characterization and the projection of anticipated commercial-scale process environmental characteristics are gaining appropriately increased attention.

Composition and Focus of the Panel

Panel members, ranging from life scientists to process engineers, were selected for their expertise in one or more of the key activity areas outlined in Table I. Following a series of plenary discussions, members distributed themselves among four working groups drawn primarily on disciplinary grounds:

Group I. Chemical Measurements: Sampling, Preservation, and Analysis

Group II. Bioassay Measurements: Sampling, Fractionation, and Analysis

Group III. Process Environmental Measurements: Characterization and Scaling

Group IV. Control Technology Measurements: Treatability and Performance

TABLE I

MAJOR SOURCE CHARACTERIZATION ACTIVITIES CURRENTLY ASSOCIATED WITH COMMERCIAL-SCALE COAL CONVERSION ENVIRONMENTAL ANALYSIS

I. Sample Characterization • chemical measurements • bioassay measurements	• development and verification of techniques for the identification of species of potential concern • application of existing and newly developed techniques to the characterization of generic samples
II. Process Characterization • chemical measurements • bioassay measurements	• site-specific determination of the fate of suspected health and environmental pollutants existent during processing • site-specific screening evaluation for the presence of as yet unidentified hazardous constituents by techniques developed in Sample Characterization-related activity • formation of experimental investigations and related data analysis to insure the scalability of results for use in subsequent commercial-scale projection efforts and the relationship among the results and range of possible operating conditions
III. Effluent Treatment Characterization • chemical measurements • bioassay measurements	• generic and process-specific determinations of both the treatability of coal conversion wastes by various unit operations and the influence of contaminants on performance • determinations of the fate of critical environmental species, e.g., trace metals and PNA's, in effluent treatment systems
IV. Projection of Commercial-Scale Effluent Discharge Data Bases	• scaling of process characterization and treatability characterization data to reflect anticipated commercial-scale process configuration, operating practice, and effluent control systems

A fifth group devoted to ambient and occupational monitoring was also assembled. Results of that group's activity are presented in another section of the Workshop Report and are therefore not repeated here.

Panel Groups I and II addressed a range of disciplinary problems and needs associated with both sample and process characterization. Group III addressed issues associated with the application of chemical and bioassay measurements to commercial and scalable, site-specific process characterization, and group IV addressed issues associated with characterizing the treatability of raw effluent-bearing process streams and wastes.

Structure and Reporting of Panel Deliberations and Findings

Each of the Panel's four groups addressed the same three basic questions in the course of their deliberations:

1. Existing Data Base: To what extent have process effluents from coal gasification and/or liquefaction processing already been characterized, and to what extent are pilot plant results expressible as projected discharges from a commercial-scale facility?

2. Existing Tools, Protocols: To what extent are state-of-the-art tools and protocols adequate for additional characterization?

3. Needed Tools, Techniques, Protocols: What extensions of present state-of-the-art tools, techniques, and protocols are needed to improve effluent characterization efforts and permit expanded projections to commercial-scale process environmental discharges.

The bulk of Panel effort was devoted to deficiencies in current practice. However, for completeness limited comments are offered regarding existing data and techniques. What follows is first a synopsis of panel findings and then a detailed reporting of individual group deliberations as well as a somewhat more extended statement of individual findings.

SYNOPSIS OF PANEL FINDINGS

Nature and Extent of Existing Environmental Data

Commercial-scale discharge projections for criteria pollutants have been published in Lurgi environmental impact statements and DOE-sponsored conceptual commercial design studies on the basis of engineering calculations. Measured data available are those from a growing number of government-sponsored PDU and pilot-scale environmental sample and process characterization efforts. These data provide a framework for the screening of potential environmental characteristics in coal conversion systems, though they generally do not yet provide a quantitative basis for process-specific commercial-scale projections. Sample characterization efforts provide a key basis for the screening of samples both for major known environmental species and for the identification of unknown, potentially hazardous species. They have and continue to provide the framework for development and refinement of analytical techniques and protocols. Process characterization offers the potential for scalable application of sample characterization techniques to the analysis and quantitative projection of process-specific environmental characteristics. Process characterization at current process development unit (PDU) and pilot scales of development is dependent upon the accessibility of process environmental samples of known representativeness in sufficient quantities for meaningful analysis.

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Adequacy of State-of-the-Art Environmental Tools and Protocols

Two facts were evident early in the course of the workshop:

1. The limited quantitative commercial-scale data base immediately available (either measured or projected) for assessment of process-specific coal conversion environmental impacts was not initially apparent to those outside the source characterization panel.
2. Use and extension of the current data base is a multidisciplinary task requiring attention to both the complexities of coal-derived sample preservation and analysis and the challenges associated with representative sampling and data scaling in PDU and pilot systems.

Other Workshop panels dealt with the reality of the first fact by stressing techniques and methodology. The Source Characterization panel addressed the second fact primarily by identifying interfaces and developments needed to facilitate the interpretation and extension of currently available commercial data bases and techniques. To the limited extent that integration of existing techniques and data was directly discussed, panel members pointed out the challenge of assessing the effectiveness of such integration in commercial data base generation, since this requires a perspective which necessarily extends across all of the individual disciplines involved in source characterization. While the need for this type of integration is appreciated, efforts to develop the capability have only recently been initiated.

Needed Developments: Tools and Protocols for Source Characterization

The panel identified needs for a number of improvements and extensions to present tools and protocols for source characterization. The thrust of member comments fell broadly into two major categories:

1. Extensions to chemical and biological tools and protocols for the identification of potential environmental hazards through sample characterization.
2. Development and/or documentation of engineering tools, techniques and protocols for the representative collection and scaling of site-specific process and environmental data through process and effluent treatment characterization.

Traditional agency funding structures fall primarily along disciplinary lines. Accordingly, panel deliberations are addressed in that context. However, it must be noted that effectiveness in both sample and process characterization depends upon strong synergism between these activities. Consideration should be given to the proper stimulation of this interface.

Chemical Measurements: Sampling Preservation and Analysis

As is summarized in Table II, a total of ten specific issues/problems associated with chemical measurements were identified by the panel. In each instance, identified problems can be related to one or more of the three basic facets of chemical measurement: sample collection, sample preservation, and sample analysis. Particular problems associated with sample characterization-related activities* included: (1) representativeness of samples, (2) stability

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*See Table I for a description.

TABLE II

SUMMARY OF ISSUES AND NEEDED PROJECT ACTIVITY
AREAS: CHEMICAL MEASUREMENTS

CHEMICAL MEASUREMENTS: SAMPLING, PRESERVATION AND ANALYSIS

Issues/Problems	Recommended Project Activity
I. Quality controls, standardized laboratory practices and quality assurance procedures	
1) Tools	• development of a set of standard reference research materials
	• establishment of a repository for standard reference materials for research
	• standardization of techniques for the calibration of laboratory methods
	• documentation of a set of validated sample preservation techniques
2) Protocols	• development of procedures for representative incorporation of standard reference materials into test programs
	• validation of sample/analytical work-ups and instrumental analyses
	• establishment of guidelines for the documentation of laboratory calibrations, sample processing, and the citing of data confidence limits
II. Representative high temperature, high pressure sampling systems	• continued development of probes and sampling trains capable of: - operating at high pressures and temperatures typical of gasifier environments - avoiding losses of sample components during depressurization - insuring stability of the sample once collected - representative collection of stream particles and liquid aerosols
III. Representativeness and stability of liquid samples	• development of procedures for establishing the representativeness of a sample

TABLE II (Continued)

CHEMICAL MEASUREMENTS: SAMPLING, PRESERVATION AND ANALYSIS

Issues/Problems	Recommended Project Activity
	• review and analysis of liquid sample stabilities and preservation techniques • development/refinement of techniques for: - sampling of volatile organics and dissolved gases in liquid streams - stable storage of liquids
IV. Representativeness/stability of inhomogeneous solid samples (organic as well as inorganic) having wide particle size ranges	• evaluation of the extent of unpreserved sample degradation • evaluation of candidate preservation techniques for unstable solids, e.g., freezing, inert gas blanketing • development of indicator compounds to monitor stability of solids in storage
V. Representative characterization of fugitive emissions	• development and validation of techniques for determining mass rates of fugitive emissions • development of screening or continuous workplace monitoring techniques
VI. Recovery of organics from solid and liquid phase samples	• development and validation of improved techniques for concentrating and recovering organics from coal liquids (aqueous and hydrocarbon) and solids • development of techniques for accommodating emulsions, effervescence, and foaming during purification of organics
VII. Comprehensive analysis of recovered organics	• development of instrumental methods of analysis (identification and quantification) of polar and nonvolatile organic compounds

TABLE II (Concluded)

CHEMICAL MEASUREMENTS: SAMPLING, PRESERVATION AND ANALYSIS

Issues/Problems	Recommended Project Activity
	• development and application of instrumental techniques for the elucidation of isomeric structures of selected organic compounds
	• development and application of instrumental methods for identification and quantification of: - heavy hydrocarbon residues - low concentration heterocyclic, N,S, and O-containing compounds
	• development of low-level detection and measurement capabilities for organic sulfur compounds
	• development of techniques for on-site analysis of organics in raw liquid and solid samples
VIII. Inorganic Characterization of samples	
1) Methods development	• development of improved techniques for identifying and measuring selected inorganic compounds
2) Characterization	• speciation of selected inorganic constituents in a representative range of coal conversion materials
	• analysis for selected organometallics in a representative range of coal conversion materials
IX. Physical Characterization of solid samples	• development of rapid methods for the determination of particle size distributions (including liquid aerosols), pore size distribution and particle density
X. Development and Automation of sampling and instrument analyses	• initiation of development of on-line instrumentation capability for demonstration plant-scale analysis (3- to 5-year horizon)

of samples once collected, (3) limitations of current analytical procedures for the identification and quantitation of known or potentially significant environmental species, and (4) lack of an established protocol for quality control in all phases of chemical measurement activity. Similar problems are seen for process and effluent treatment-related characterization activities.*

Bioassay Measurements: Sampling Fractionation and Analysis

Panel members strongly endorsed the growing and useful contribution of bioassay measurements to the environmental characterization of a source. As is summarized in Table III, two major issues/ problems were identified. The first, lack of representative samples in adequate quantities for analysis is similar to a statement made regarding chemical measurements. The second reflects the panel's basic position that bioassay measurements should ultimately be employable as a basic tool in environmental characterization comparable to that of present chemical measurements. As is noted in Table III, a number of specific developmental activities are necessary if this objective is to be met.

Process Environmental Measurements: Characterization and Scaling

At the PDU and pilot stages of coal conversion technology development, the panel found scaling to be the central issue in the

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*See Table I for a description.

TABLE III

SUMMARY OF ISSUES AND NEEDED PROJECT
ACTIVITY AREAS: BIO-ASSAY MEASUREMENTS

BIOASSAY MEASUREMENTS: SAMPLING, FRACTIONATION AND ANALYSIS

Issues/Problems	Recommended Project Activity
I. Need for acquisition of defined samples in sufficient quantity for bioassay and need for implementation of direct bioassay services.	• determine the relationship between obtained test samples and actual effluents • develop and implement a sampling methodology which allows determination of sample bioactivity as a function of process operating conditions • develop and implement methods for the acquisition of airborne particulate samples for bioassay evaluation • implement methodology for the support of short-term and chronic bioassay testing • institute a quality accurance program through the use of standard reference materials for chemical preparation and bioassay work on coal-conversion-related materials • develop surrogate samples for biological studies of fugitive emissions studies
II. Need to implement bioassay chemistry for the identification of unknown biologically active constituents and to identify and quantify known biologically active constituents.	• development of sample separation schemes tailored specifically to bioassay requirements • development of a compatible set of chemical and bioassay sample fractionation procedures • development of a suitable methodology for the identification and quantification of bioactive components, particularly structural, e.g., isomers • development of a methodology for correlating chemical and bioassay analytical results

application of chemical and biological measurements to process characterization. While the science of scaling is a fundamental and well-developed facet of process engineering, its application to environmental analysis to date has been limited. In coal conversion technology development, experience with environmental scaling evolved largely in the DOE coal gasification pilot plant program. Accordingly, issues and problems addressed by the panel were based first on experience gained from gasification programs. Deliberations were then extended to consider similarities and contrasts in the role of scaling in liquefaction analysis.

As is summarized in Table IV, the panel identified a number of specific project needs relative both to the basic aspects of scalability and to their application in the generation of scalable coal gasification environmental data bases. Although direct experience is limited, the panel did make a number of recommendations regarding the applicability of gasification environmental data to liquefaction systems and the generation of scalable liquefaction environmental data bases.

Control Technology Measurements: Treatability and Performance

Since most PDU and pilot-scale equipment is either not equipped with control technology at all or equipped with nonscalable control systems, independent assessment of the treatability of raw process wastes is typically required. As is summarized in Table V, the panel briefly addressed the relevance of existing treatment capability in

TABLE IV

SUMMARY OF ISSUES AND NEEDED PROJECT ACTIVITY AREAS:
PROCESS ENVIRONMENTAL MEASUREMENTS

PROCESS ENVIRONMENTAL MEASUREMENTS: CHARACTERIZATION AND SCALING

Issues/Problems	Recommended Project Activity
I. Relationship of scalability to environmental characterization of a process	
1) Delineation of basic scalable relationships	• development and documentation of a generic understanding of the major influences of process variables on the fate of S, N, HC's and trace elements in coal conversion
	• formation of a guide to the selection of process variables in site-specific studies which might be expected to correlate with variable effluent production
2) Impact of scalability issue on the tools and techniques of data base generation	• development of improved flowrate measurement techniques for slurry streams, raw product gases, and liquids for conversion of environmental data from nonscalable concentrations to more scalable mass flows
	• improvements in sampling techniques necessary to the determination of process variable/effluent production relationships
	• statement of guidelines and their initiation for scalable environmental characterization of process at the key stages of process development
3) Relationship of scalability to occupational health characterization	• development of strategy for scalably characterizing potential occupational health factors in subcommercial-scale systems
	- evaluation of the relative merits of process stream characterization as one technique for PDU and pilot-scale analysis of the potential toxicity of a process stream
	- identification of key "tracer" components for work area monitoring and development of correlations between "tracer" exposure and total hazard

TABLE IV (Continued)

PROCESS ENVIRONMENTAL MEASUREMENTS: CHARACTERIZATION AND SCALING

Issues/Problems	Recommended Project Activity
II. Generation of scalable gasification effluent data bases	
1) Orientation of field sampling programs	• Statement and execution of clear guidelines for specification of scalable points for experimental analysis at each stage of process development. This requires: - development of techniques for identifying scalable links between commercial and subcommercial-scale experimental equipment
	• formulation and use of test plan strategies which can produce sufficiently accurate data to insure the delineation of any significant process variable/effluent production relationships. Factors involved include those cited earlier in Tables I and II, i.e. sample stability and analysis
	▪ review and scheduling of sampling activities to insure analysis of effluent production characteristics over a full range of potential process operating conditions
	• evaluation of the role and value of material balance efforts as a component in environmental characterization efforts at the various stages of process development
2) Criteria for the prioritization of characterization efforts given limited time and budget.	• development of bioassay procedures with known confidence levels, with an emphasis on reduced probabilities of false negative responses and a capability for semi-quantitative characterization of response
	• evaluation of EPA MEC's through bioassay characterization of analytically well-defined samples of coal conversion materials
3) Fugitive emission characterization	• evaluation of the merits of process stream characterization as a technique for analysis of potential fugitive emission characteristics at PDU and pilot scales of data base development

TABLE IV (Continued)

PROCESS ENVIRONMENTAL MEASUREMENTS: CHARACTERIZATION AND SCALING

Issues/Problems	Recommended Project Activity
	• development and documentation of techniques for the identification and quantification of fugitive emissions and their sources, particularly in demonstration and commercial-scale systems • development of reliable techniques for determining the rates of fugitive emissions
III. Applicability of coal gasification environmental data to liquefaction systems	• analysis of the relationships between gasification and liquefaction systems for environmental similarities and differences with an emphasis on the strengths and weaknesses of assessing liquefaction environmental characteristics on the basis of coal gasification experience
IV. Generation of scalable liquefaction effluent data bases	
1) Initiation of scalably directed process-specific programs	• review and correlation of existing environmental data against process variables to the extent possible for purposes of: - illustration of any value of such correlations to the understanding of process environmental characteristics - demonstrations of the strengths, weaknesses, and needs of the existing data base • Development of new site-specific field environmental characterization programs designed to generate data on major and trace health and environmental pollutants in relation to the dynamics of coal liquefaction. Programs would be directed toward: - defining the process data needed for proper scaling of environmental data - utilizing process data to determine the scalability of plant environmental data

TABLE IV (Concluded)

PROCESS ENVIRONMENTAL MEASUREMENTS: CHARACTERIZATION AND SCALING

Issues/Problems	Recommended Project Activity
2) Management of liquefaction environmental characterization activities	• establishment of a series of site-specific environmental contractors chartered to develop the environmental data bases at individual liquefaction facilities
3) Delineation of basic process variable/effluent production relationships	• development of a series of laboratory and/or PDU scale studies of basic effluent/process variable relationships in liquefaction processing with emphasis on catalyst sensitivities
V. Projection of commercial-scale environmental characteristics from sub-commercial-scale data	• development and documentation of guidelines for analyzing differences between commercial and experimental process conditions and projecting the impact of these differences on commercial-scale effluent production
	• formulation of guidelines for the scaling of experimental data from various types and sizes of equipment

TABLE V

SUMMARY OF ISSUES AND NEEDED PROJECT ACTIVITY AREAS:
CONTROL TECHNOLOGY MEASUREMENTS

CONTROL TECHNOLOGY MEASUREMENTS: TREATABILITY AND PERFORMANCE

Issues/Problems	Recommended Project Activity
I. Applicability of analogous commercial industry experience (petroleum, by-product coking) in defining the treatability of coal conversion wastes	• Evaluate and delineate the significant limits to the analogy between commercial industrial waste treatment and coal conversion waste treatment. Recent assessments in this area may need to be verified through field tests.
II. Purification of raw product gases	
1) Establishing a scalable composition of raw gas into gas purification	• In those cases where nonscalable systems are employed for the quenching of raw product gas, define a procedure for citing gas compositions upstream of the quench system--either by direct measurements or by combining measurements of the gas and liquid streams entering and leaving the quench tower. • develop a systematic modeling procedure for distributing raw product gas components across commercially significant quenching systems as the basis for citing gas compositions into gas purification systems
2) Fate of minor and trace effluent constituents in gas purification systems	• generate comprehensive effluent data bases on the fate of minor (e.g., trace metals, PNA's) environmental components in scalable gas purification equipment in place at existing pilot facilities (e.g., Bi-Gas Selexol system, C-E Stretford system)
3) Particles and aerosols	• develop removal efficiency data bases on such removal systems as cyclones and electrostata precipitators
III. Treatment of Raw Wastewaters	
1) Establishing a scalable composition of raw wastewater for treatment analysis	• formalize procedures for converting generally nonscalable PDU and pilot-scale wastewater concentration data to more scalable mass production rates per unit of coal feed

TABLE V (Concluded)

CONTROL TECHNOLOGY MEASUREMENTS: TREATABILITY AND PERFORMANCE

Issues/Problems	Recommended Project Activity
	• develop procedures (including quench modeling where appropriate) for factoring out the effects of nonscalable PDU and pilot-scale raw product gas quench systems on the compositions of raw product gas quench condensates collected from such systems for treatability analysis
	• formalization of the issues to be addressed, optimized and documented in the presentation of any site-specific water management strategy
	• identification and experimental demonstration of minimum water quality criteria for recycle/reuse of coal conversion wastewater, e.g., as cooling tower makeup, as boiler feedwater, as process water
3) Establishing the performance of major wastewater treatment system components on coal conversion wastes	• evaluation of the performance of a range of wastewater treatment system components, e.g., O_2-enriched biological oxidation, anaerobic treatment, ion exchange, ozonation, on established, scalable wastewater samples
4) Fate of minor and trace effluent constituents in wastewater processing	• generate comprehensive effluent data bases on the fate of minor and trace environmental components (e.g., trace metals, PNA's) in various scalable wastewater treatment processing steps, e.g., steam stripping, phenolic extraction, biological oxidation, ion exchange
IV. Processing and disposal of solid wastes	
1) Establishing whether or not specific solids present any potential environmental problem	• development of a comprehensive standard procedure for experimentally establishing the leachability of various coal conversion solid wastes
	• evaluation of the disposal characteristics of waste treatment sludges, particularly biological treatment sludges
	• evaluation of coal conversion wastes in light of provisions of the Resource Conservation and Recovery Act

analogous commercial industries to the management of coal conversion wastes, concluding that no definitive systematic analysis of the proper bounds of the analogy argument has been conducted. The bulk of the panel's attention was then focused on a delineation of major issues and project needs for the development of scalable treatability and performance data on raw gas, liquid, and solid waste treatment systems, respectively.

CHEMICAL MEASUREMENTS: SAMPLING, PRESERVATION AND ANALYSIS

Panel deliberations associated with chemical measurements focused on six broad issues:

1. Interfaces between chemical and bioassay characterization of samples: sample preparation, analysis
2. Quality control methods, laboratory practices, and assurances
3. Gas, liquid, solids, and fugitive emission sampling
4. Organics characterization: sample consolidation, species identification
5. Inorganic characterization: species identification, automation
6. Physical characterization

Issue I will be discussed in the next section of this report concerned with bioassay measurements. The remainder of these issues are discussed below.

Quality Controls, Laboratory Practices and Assurances

The Problem

Sampling, preservation, and analytical procedures initially adopted from petroleum and by-product coking practice and subsequently modified in response to unique characteristics observed in gasification and liquefaction processes continue to show evidence of instability and bias due to a complex and as yet uncharacterized matrix of interactions within samples. While relatively large biases in analytical data can be tolerated for many applications, selected uses of data require reasonably high confidence limits, most notably data used in the development of process specific scaling relationships for various effluent species (refer to the report section which addresses process characterization activities). At present, neither achievable nor actual confidence limits are reported for species analysis on coal gasification and liquefaction materials.

Tools Needed

Several tools are needed for the development of an effective quality assurance program:

1. Generation of standard reference materials
2. Development of a repository of reference materials
3. Development of techniques for the calibration of laboratory methods
4. Development/validation of sample preservation techniques, procedures

To a large extent, existing programs do not address items 1 through 3; item 4 is gaining increasing attention, particularly as analytical methodologies are applied in site specific process characterization efforts. The panel assigned a high priority to the development and documentation of the above tools, at least for high priority effluent species.

Protocols Needed

In conjunction with the above tools, several protocols need to be developed and/or defined:

1. Procedures for representative incorporation of references (internal standards) into samples

2. Procedures for the validation of sample/analytical workups, instrumental analysis

3. Minimum standards for the documentation of laboratory calibrations, preservation and analytical procedure validations, and data confidence limits in applications of chemical measurement to process specific environmental characterization efforts

Research Projects

Portions of needed tools and protocol development can proceed under existing agency funding umbrellas. However, separately initiated research projects may prove necessary for:

1. Development of an effective validated system of reference materials and procedures for their use

2. Testing and documentation of the confidence limits of validated characterization procedures on a range of coal gasification and liquefaction process and sample types

3. Establishment of minimum standards for documentation of characterization procedures which can serve as analytical validation of site specific process characterization data bases

Gas Stream Sampling

The Problem

To be of use in scalable site-specific process characterization, gas sampling procedures must be capable of producing representative samples which can be effectively stabilized in sufficient quantities for both chemical and bioassay analysis. As is noted later in the discussion of process characterization activities, sampling points of greatest value tend to coincide with extreme process conditions of pressure, temperature, and multiphase flow. Techniques need to be developed and/or refined to overcome the problems associated with sample collection at such points. In the case of site-specific characterization activities, there is an additional requirement that the turnaround time for a single sampling must be short enough to permit the meaningful collection of time series data on gas composition. (See section on process characterization for relevance of such sampling.)

State-of-the-Art

Existing data demonstrate our inadequacy in collecting representative, stable samples in sufficient quantities for analysis from complex high temperatures, high pressure gas streams. EPA's SASS train has been employed extensively but with widely varying degrees of success. Inherently long sampling times render this system impractical for time series analysis even in those situations where sampling problems are considered manageable.

Research Project Needs

The panel assigned a high priority to the need for development and/or validation of procedures and equipment which are:

1. Capable of operating at high pressures and temperatures typically encountered at the most representative sampling points in many gasification and liquefaction systems
2. Compatible with necessary preservation procedures to avoid losses of sample components and to insure the stability of a sample once collected
3. Capable of insuring the representative collection of stream particles or liquid aerosols in the size ranges and quantities necessary for meaningful analysis

4. Capable of successfully managing the interaction of effluent species which are partially soluble in, or reactive with, condensibles which appear at various points in the sampling and collection system

Liquid Stream Sampling/Preservation

The Problem

There is a need to examine closely whether or not samples obtained from within a process or a final effluent are representative of the system sampled and to develop or refine techniques where necessary.

State-of-the-Art

Currently available techniques have either not been validated or have been found to have one or more problems.

Research Project Needs

The panel identified a series of candidate research projects which respond to perceived needs:

1. Development of sampling techniques for high pressure/high temperature liquid streams

   The principal objective would be to develop a system which would overcome degassing and solidification problems which have been sources of nonrepresentativeness in past gasification and liquefaction sampling.

2. Development and evaluation of liquid sample preservation techniques

   Existing programs have generated some information on the stability of various chemical classes in liquid samples. The objectives of a new effort would be (1) to systematically determine the degrees of liquid sample instability in various types of gasification and liquefaction samples and (2) to devise procedures for insuring the stability of such samples.

3. Development of a procedure for designing liquid sampling strategies

   Existing programs have to some degree addressed the issue of stream variability and the proper sampling schedule to accommodate this. The objective here would be to develop statistical sampling frequency and duration to control the mean and standard deviation of stream composition results.

4. Development of methods for sampling volatile organics in liquid streams

   The objective is to develop and validate a method/device which allows the representative collection of volatile organics dissolved in liquid streams. Current sump knock-out devices are inadequate.

5. Evaluation of the storage techniques and stability of liquid samples

   The objective is to determine the potential transformation reactions (e.g., oxidation, polymerization) which may occur during sample storage and distinguish between components initially present in the sample and those present as a direct result of storage.

Solid Stream Sampling

The Problem

Standard procedures available from ASTM and EPA are complicated when gasification and liquefaction materials have extremely wide size ranges and inhomogeneities. Available data on both the composition and the stability of solid samples, particularly organics, are limited.

Research Project Needs

The panel identified four priority research project needs:

1. Examination of existing data for correlation between homogeneity and specific sample parameters, e.g., particle size, major components, organic functional groups

Ultimately what is needed is an evaluation of the prospects for selecting indicator variables which may be used as measures of homogeneity for classes of solids, e.g., coal, ash, char, mineral residue.

2. A series of time vs composition studies on various solids samples with emphasis on organic components and bioassay response to determine the significance of sample degradation
3. Development and testing of solids preservation techniques such as freezing and inert gas blanketing for those sample types shown to undergo substantial degradation
4. Development of indicator compounds to monitor the stability of solid samples in storage; techniques might include isotropic or radioactively labeled compounds.

Fugitive Emission Sampling

The Problem

There are at present no established procedures for the measurement of fugitive emission characteristics in coal gasification and liquefaction. There is a need for (1) the determination of mass rates of fugitive systems, emissions from large-scale processes, and (2) quantification of individual species or classes of compounds within emission streams either at each source or a statistical sampling of source points.

Research Project Needs

The panel recommended two specific research projects, although they assigned them relatively low priority in advance of the startup of demonstration-scale systems:

1. Development of procedures for direct measurement of fugitive emissions from coal gasification and liquefaction processes, using recent developments in petroleum refinery

sampling, and testing their effectiveness at selected operating coal processing facilities

2. Development and application of procedures for the direct measurement of flare emissions either by injection of a tracer or by identification of an inlet stream component for which material balances and profiles of concentration ratios in emission flows can be identified for use in tracking the fate of components of environmental interest

Techniques for Recovery of Organics from Solid and Liquid Phase Samples

The Problem

At issue is the reliability and accuracy of work-up procedures for characterization of organics in liquids and solids. Efficiencies for samples can vary significantly even though they come from the same process and sampling matrix. Some research has been conducted to establish recovery efficiencies and problems in procedure; however, the bulk of this work remains unvalidated. Ultimately there is a priority need for techniques which allow purification and recovery of organics while not compromising the accuracy and reproducibility of the data.

State-of-the-Art

Current techniques concentrate organics by passing liquids through sorbents, or purging out volatiles with helium gas; however, foaming is a serious problem with the latter method and recovery and collection efficiency is a problem with the former. Emulsions and effervescence are persistent problems with extraction equipment.

Research Project Needs

The panel identified two high priority research projects:

1. Development and application of improved techniques for concentrating and recovering organics from coal conversion liquids and solids
2. Techniques for accommodating emulsions, effervescence, and foaming during purification of organics from coal conversion liquid and solid samples

Analysis of Hydrocarbon Samples

The Problem

Liquids and solids from coal conversion processes contain organic constituents which have not been identified and quantified because of the inadequacy of state-of-the-art analytical techniques. Organic chemical classes with multifunctionalities may make up as much as 60 percent of the organics in the sample. The composition of these samples needs to be comprehensively characterized for identification of those species which may pose a potential health hazard. It is presently not possible to detect and identify many candidate species.

State-of-the-Art

Some promising tools such as field desorption mass spectroscopy and Fourier transform infra-red spectroscopy show promise; however, considerable investigations, modification, perfection, and new design research are needed. At present little reliable information exists on up to $\sim$ 80 percent of some organic samples.

Research Project Needs

The panel identified six high priority research project needs:

1. Development of instrumental methods of analysis (identification, quantification) of polar and nonvolatile organic compounds in coal conversion liquid and solid effluents

   The objective is to provide a basic capability at present unavailable.

2. Development and application of instrumental techniques for the elucidation of isomeric structures of selected organic compounds present in coal conversion liquids and solids

   The objective is to provide a capability for separation and identification of isomeric organic compounds, particularly those of interest in health effects research.

3. Development and application of instrumental methods for identification and quantification of constituents in heavy residues from coal conversion systems

   The objective is to provide instrumental capability for the analysis of high molecular weight (500 to 1000+) heavy residues (e.g., char, tar).

4. Development and application of instrumental methods for identification and quantification of heterocyclic compounds in liquid and solid samples from coal conversion processes

   The objective is to develop methods for identification and quantification (to 1 ppb level) procedures for S, N, O - containing chemical classes of hydrocarbons. Organics having the greatest known biological activity fall into these groups and are now only partially measurable by state-of-the-art techniques.

5. Development and application of instrumental techniques for identifying various forms of organic sulfur compounds in liquid and solids samples from coal conversion processes

   The objective is to provide low detection level (0.1 ppb) detection and measurement capabilities for such organic sulfur forms as sulfuric acids, sulfones, sulfates, sulfonates, and sulfides.

6. Development and application of instrumental methods for direct in situ analysis of organics in liquid and solid samples from coal conversion processes

   The objective is to develop procedures for analyzing samples where chemicals (e.g., sulfuric acids) are not extractable from the sample.

Inorganic Characterization of Samples

The Problem

Commonly used instrumental procedures for inorganic analysis have to be examined in light of the sample collection techniques involved. More data are needed on the reliabilities and sensitivities of the procedures currently in use. More information regarding specific elements and their biologically active forms are needed to determine what types of analyses would provide the most substantive data. New or novel instrumental techniques should be investigated and developed for possible use in these studies.

State-of-the-Art

There are presently some speciation techniques available for mercury, arsenic, and selected carbonyls. There are a number of techniques such as atomic absorption, x-ray fluorescence, and instrumental neutron activation available for total inorganic analysis but additional validation studies are needed. Some forms of Auger and ESCA are used for the analysis of surfaces, however these methods are not sensitive enough and are extremely costly. Techniques for inorganic speciation and the detection of specific compounds is largely unknown. No inexpensive, simple, but reliable methods exist for direct measurement of inorganic species, particularly for anions and trace metals in gases.

Research Project Needs

Three projects were considered of major importance by the panel:

1. Speciation of inorganic constituents in a cross-section of coal conversion materials
2. Investigation of organometallics in a cross-section of coal conversion materials
3. Development of direct methods for identifying and measuring inorganic compounds in coal conversion materials

The speciation project would provide data on the specific capabilities, limitations of present techniques for inorganic species analysis. An in-depth search for and study of organometallics would be of benefit not only to coal conversion research but others as well. Development of direct measurement techniques would provide a means to circumvent present problems of isolation and concentration of specific compounds and could lead to improvements in the analysis of anions in solution.

Physical Characterization of Samples

The Problem and State-of-Art

Few data are available concerning the physical properties of effluent-bearing streams from coal conversion systems. Rapid and possibly on-line methods are needed to provide such data. Physical properties of interest include viscosity, particle-size distribution, pore-size distribution, density, and rapid boiling point determinations. Physical properties such as sorption of gases by chars and changes in viscosity following exposure to air and elevated temperatures can alter assessments of needs for the treatment of materials.

Research Project Needs

The panel assigned a medium priority to the initiation of two research projects:

1. Development of on-line instrumentation for the determination of the viscosity of coal derived liquids
2. Development of rapid methods for the determination of particle size distribution, pore size distribution, and density of particulates and solids residues from coal conversion processes

Automation of Sampling and Instrumental Analysis

The Problem and State-of-Art

At some point in the evolution of individual coal conversion processes (most probably at the demonstration-scale), on-line process stream sampling and analysis of selected environmental species are appropriate. Limited efforts to employ and/or modify existing automation systems have demonstrated the need for equipment designed specifically to accommodate the vagaries of coal conversion systems.

Research Project Needs

Although the time frame for first application of significant automated sampling and analysis is 3 to 5 years, the panel concluded that some attention should be devoted now to the development and perfection of automated gas chromatography/mass spectrographic systems to insure their availability when needed. This will require automated, fast response techniques. Automated analysis, particularly for gas streams, is necessary to track changes in process conditions and their relationship to emissions. A specific need is the development of a method for interfacing sensitive instrument probes and equipment with the extremely reactive and dirty gas streams containing high levels of condensables. Such a method must not result in a change in the composition of the gas being measured.

BIOASSAY MEASUREMENTS: SAMPLING FRACTIONATION AND ANALYSIS

The panel considered two broad issues associated with bioassay measurement of coal conversion materials and recommended a set of actions for each:

1. Need for acquisition of defined samples in sufficient quantity for bioassay analysis
2. Need for implementation of bioassay chemistry for the identification of unknown biologically active constituents and for the identification and quantification of known biologically active constituents

In each case, specific problems were identified and research objectives defined; these are reviewed below. Independent of specific facets of sample collection, preparation, testing, and chemical analysis, it was the consistent consensus of the panel that future coal conversion-related bioassay activities should be carried out as much as possible on site-specific, process-related samples. This will require a close coordination between bioassay analysts and plant process engineering personnel. Appropriate attention should be devoted to the development of necessary protocols to insure an availability of meaningful samples.

Problems/Needs: Acquisition of Defined Samples

Relationship of Test Samples to Actual Effluent

Need

Materials available for biotest often are not actual effluents. Past and future studies using these materials must be related to actual plant effluents to make such studies relevant. This task may be accomplished by determining relative concentrations of bioactive compounds and the effect of relevant physical properties (such as particle size or specific surface area) on bioavailability. The panel outlined the following four-part strategy for addressing this overall problem:

1. Development of bioassay data on combination of surrogate effluents
2. Chemical identification and quantification of bioactive subfractions or species in samples
3. Chemical quantification of bioactive fractions or compounds in actual effluent
4. Determination of the modifying effect of relevant physical properties of the actual and surrogate effluents on biological properties

Since effluent materials are complex mixtures of chemical compounds that often cannot be completely analyzed with available methods, optimum effluent assessment requires parallel use of bioassay and chemical analysis. Application of items 1 and 2 above are intended to develop a relationship between a biohazard and a chemically identifiable subfraction or compound in the surrogate effluent. Assessment of the hazards associated with the actual plant effluent may be determined by estimating the effect of scale-up or waste treatment on the identified bioactive component. These results must be modified to account for changes in physical properties of actual versus surrogate effluents, e.g., changes in an identified respirable hazard due to changes in effluent particle size.

State-of-the-Art

Presently available bioassay data are not relatable to process streams. Ames test data on potential effluents are becoming available for some processes under a few operating conditions; however, parallel use of bioassay and chemical identification is for practical purposes not yet underway. Much of this work has awaited the operation of suitable coal conversion plants. Parallel chemical support for bioassay work is being developed in a limited fashion but is in need of additional support. Ames test, inhalation studies, and mouse skin painting studies are the only chemically related bioassay activities being supported at the present time. Determination of modifying physical properties is not being done and awaits effluent samples from conversion plants.

Relationship of Samples to Process Conditions

Need

Bench- and pilot-scale coal conversion systems seldom run at the same operating conditions that a full scale plant would use. Additionally the process and effluent streams will be treated in different manners. To develop sufficiently flexible bioassay data in order that meaningful environmental impact assessments of full-scale plants may be made in a timely fashion, one must assess the changes in bioactivity of process and effluent streams as a function of plant operating conditions. In principle this could be achieved through chemical and physical analysis of plant streams. However, the complex chemical makeup of these materials precludes complete characterization and challenges the forefronts of analytical chemistry. The need for timely bioassay information requires parallel bioassay and chemical analyses of coal conversion materials. These studies must be related to process conditions.

State-of-the-Art

At present there are essentially no data available. There are isolated examples of relationships between process variables and various traditional effluent species (e.g., phenols, NH_3), and a preliminary methodology for the construction of such data bases has been proposed. There is only one funded project currently in the early stages of development directed toward the generation of a bioassay oriented correlation with process variables (Argonne National Laboratory).

Acquisition of Airborne Particulates

Need

The panel identified a need for the following specific data for analysis of the implications of bioassay information:

1. particle size distribution
2. mass loading
3. organic and inorganic composition as a function of particle size
4. specification of the route employed for bioassay administration

Particle size distribution and mass loading permit determination of sampler flow rates and sample gathering times. These data permit calculations of the inhaled dose of subsequently identified bioactive components and the estimated site of deposition. Organic and inorganic composition data permit identification of bioactive constituents, determination of in vivo solubility, and estimation of target organs from bioassay data. The route of bioassay administration determines the form of the sample required and the nature of any pretreatment required, which in turn controls the design of the collection subsystem of the sampling device.

State-of-the-Art

Available high-volume ambient air samplers are only marginally effective; high-volume process samplers are nonexistent. Research grade low-volume samplers for characterization work in low-temperature, low-pressure environments are available; high-temperature, high-pressure samplers are nonexistent. At present, (1) there are not data available on fugitive and plant-maintenance-related particulate characteristics or loadings; (2) there are no data on particulate composition; (3) there is not even a "first cut" design of process sampling techniques; and (4) minimum sample requirements for bioassay testing need refinement.

Most available airborne particulate samplers are available as a result of air pollution and inhalation toxicology studies. Most of these devices are relatively small and collect insufficient samples for bioassay. High-volume samplers for air monitoring are currently available, but collect their samples in forms which make recovery difficult or impossible. The Maxi Sampler (Dick Thompson, EPA) operates at 20 m^3/min and collects 2 size fractions cut at 3.5-1.7 m and 1.7 m. This sampler uses an electrostatic precipitator scheme to deposit the collected material in a recoverable form. Modifications of such a device for specific application will permit collection of material for screening bioassays. Collection of material for low-level chronic study is not available, but extension of existing methods should produce sampling equipment in 2-1/2 to 3 years after initi[illegible]f a development program.

Material collection from process streams is being done for limited bioassay studies on a first-time basis on a single gasifier. Samples are being withdrawn from clean and raw gas streams, cooled and diluted, and charcterized for physical and chemical properties (spark source mass spectroscopy and limited chemical analysis). Current work is scaling these sampling systems to higher volumes to obtain material for bioassay. These studies are restricted to low pressure and temperature. A few samples have been taken using a quenched probe at high temperatures and pressures at the EXXON mini-plant (reference unknown today). Beyond these pilot studies, little has been done for process analysis at stream conditions and no bioassay sampling has been done.

Methodology for Support of Chronic Bioassay Testing

Need

Chemical considerations are an essential support function to the conduct of chronic bioassay testing. Close collaboration, in fact, jointly planned design of chronic bioassay experiments is necessary to insure proper chemical preparation of the sample by techniques best suited to achieving desired results. Effective chemical support requires knowledge of the minimum sample sizes required to assure a long-term adequate supply for testing purposes. This in turn requires a knowledge of the type of assay to be performed. Since test materials must be stored and used over an extended period of time for long-term dosage studies, the detailed chemical compositions of samples must be monitored and maintained.

State-of-the-Art

There are essentially no data available on the preparation and chemical surveillance of coal conversion test materials subjected to chronic bioassay testing. One 18-month mouse skin painting bioassay experiment involving two crude coal liquids, a shale oil, a natural petroleum mixture, and their polycyclic aromatic hydrocarbon isolates is partially complete. Gas chromatographic profiling is being used to monitor the stability of the samples.

Quality Assurance: Development of Reference Materials

Need

As in other fields of analysis, there is a need for quality assurance in the generation of coal conversion-related bioassay data across an increasing number of diverse testing laboratories. Production and use of standard reference materials represents a traditional technique for establishing and monitoring inter- and intra-laboratory performance. The problem of designating a material as a reference material, whether it be water, tar, or oil, requires careful investigation with attention to such factors as: (1) bioassay sample preparation requirements, (2) stabilities of materials to be placed in long-term storage and use periodically for inter- and intra-laboratory comparisons of sample biological activity and chemical composition, and (3) analyses of materials to determine composition with respect to selected priority compounds or compound classes.

State-of-the-Art

To date, little has been done in the area. The National Bureau of Standards has conducted limited exploratory roundrobin exercises with several laboratories in the hope of developing an initial set of recommendations for surrogate standard materials. However, these efforts have not included any bioassay characterization--only chemical quantification of a few compounds. The issue of quality assurance in complex chemical and biological analysis of coal conversion materials is so new that data are simply not available to evaluate the efficiency of a standard reference materials approach.

Fugitive Emissions: Development of Surrogate Samples

Need

Fugitive emissions represent a major potential source of worker and/or community exposure to biologically active coal conversion-related materials. A number of the ongoing investigations related to potential health and environmental effects of fugitive emissions could proceed on a more sound basis if representative sample material were available. Prototype air pollution and occupational hygiene assessments could proceed at least methodologically if meaningful surrogate samples were developed and made available. Availability of such samples would also facilitate effective chemical techniques development and validation. Finally, the suitability of bioassay testing for fugitive emission analysis could be evaluated if meaningful surrogate samples were available.

In the absence of some technique for addressing fugitive emission evaluation in advance of demonstration or commercial-scale process operation, it must be assumed that regulatory development would proceed on the basis of available indirect assessment of the potential problem.

Problems/Needs: Implementation of Bioassay Chemistry in Environmental Characterization

The panel notes that while a large variety of bioassay techniques have been explored and developed over many years, these have been utilized almost exclusively for the testing of specific new compounds, particularly in the drug, foodstuff and pesticide industries. Characterization, measurement, and monitoring of a host of coal conversion-related products, intermediates, and effluents represent a new application for existing biological protocols. Its importance to overall process environmental characterization activities promises to parallel steadily rising speculations that bioassay analysis may serve as a major criterion for the specification and evaluation of effluent control and monitoring technology, if not as one basis for the establishment of effluent guidelines themselves. To be effective in such roles, it must be possible to generate meaningful bioassay data on complex chemical mixtures in one or more combinations of virtually physical states and in a wide array of matrices. Substantial developments in the field of bioassay chemistry are needed to perform bioassays on the diverse array of complex mixtures evident in coal conversion processes. This term refers to overall separation and identification requirements especially tailored to the needs of specific bioassays. These requirements are often unique when compared to the traditional needs of the chemical analyst. For example, a whole material (often too toxic for direct bioassay) must be separated without losses under chemical and/or physical conditions which do not alter sample composition. Clearly, these requirements are necessary to achieve meaningful information ultimately. Whether the bioassay is being used to obtain an estimate of overall sample bioactivity or to obtain a chemical screening for known/unknown bioactive components, specialized bioassay chemistry is necessary to the generation of useful information.

Although historically, chemists and biologists have tended to work independently, their merger is essential to the development of effective, efficient bioassay screening and assessment techniques for coal conversion-related materials. Exploratory and developmental programs are underway at selected facilities now, including Argonne National Laboratory, Lovelace Inhalation Toxicology Research Institute, and Oak Ridge National Laboratory. Examples of early experience gained from interactive chemical and bioassay analytical work include:

1. Results of Ames testing on whole and fractionated samples suggest that synergistic and antagonistic effects within a sample may not be significant, i.e., responses to sample fractions appear to be additive.
2. Biologically active fractions have been found to contain compounds which have proven activities when assayed in their pure states.
3. Selected known biologically active compounds, e.g., azarenes, although traditionally of minor environmental importance in other industries, may represent significant factors in coal conversion process due to their substantially higher concentrations.

Bioassay-Specific Sample Fractionation Development

Need

In general, some separation of materials into chemical class fractions is required to overcome overall sample toxicity and obtain meaningful bioassay screening data. Matching a separation scheme with a bioassay technique including (1) solvent compatibility with the bioassay system, (2) quantity of sample or sample fraction required, (3) nature of recombination procedures to be employed in interpreting fractionated sample assay results, and (4) the target objectives for the assay.

Without knowledge of specific bioassay details, various separations schemes or sample pretreatments can lead to meaningless or misleading bioassay data. It is the panel's opinion that chemical treatment prior to bioassay analysis represents a critical step in the overall bioassay process and must be regarded as an activity separate from physical and chemical separations performed for purposes of chemical measurement (see previous section of this report).

State-of-the-Art

Little has been published on the application/development of separations techniques to the biological characterization of samples. The traditional application of bioassay analysis to investigations of pure compounds circumvents the significant matrix effects of complex mixtures present in coal conversion process samples.

Methodology for the Quantification of Bioactive Sample Components

Need

Development of suitable methodology for determining bioactive constituents depends entirely on a close interaction between chemical and biological analysis. Often among a group of closely related components, only one or a select set of isomers may prove to be biologically active. An iterative chemical assay-bioassay approach is needed for the identification and chemical characterization of bioactive components in complex mixtures. Progressive iterations of partitioning of a sample into increasingly bioactive fractions can lead to isolation and identification of specific active compounds. Such techniques for narrowing the overall problem of analysis of a complex mixture to a manageable chemical analysis are essential.

State-of-the-Art

Strides are being made in the identification of some well-known classes of components present in coal conversion-related materials which are biologically active, e.g., PAH's and certain nitrogen heterocyclic compounds (e.g., EPA's Multimedia Environmental Goals program). However, in general there is a lack of knowledge concerning the bulk of the components present in coal conversion materials. An expansion and verification of MEG's listings, especially with regard to pollutants associated with coal conversion may be warranted.

Correlation of Chemical and Bioassay Characterization

Need

At present, process environmental analysts presently must rely on extensive lists of hazardous and toxic substances as the basis for designs of sample screening strategies which meet requirements for identifying species which pose a potential health risk. Such a procedure is neither objective nor cost-effective, since (1) many of the presently listed compounds are not present in coal conversion systems and (2) compounds of greatest concern may be unique to coal conversion systems. What is needed is an objective technique for effectively isolating potentially hazardous components in coal conversion process streams for further analysis. A combination of bioassay screening of samples combined with isolation of biologically active chemical classes and/or selected compounds can serve as one such technique. Attention in process environmental characterization would be focused on these streams exhibiting biological activity and those chemical classes and/or compounds responsible for observed activity.

State-of-the-Art

Exploratory experimental studies in progress indicate that some correlation of biological and chemical characterization can be achieved, and such an approach offers hope as an objective procedure for the screening of coal conversion processes and the focusing of detailed attention on measured active streams and constituents.

PROCESS ENVIRONMENTAL MEASUREMENTS
CHARACTERIZATION AND SCALING

The panel considered five basic issues associated with the application of chemical and bioassay measurements to the environmental characterization of coal conversion process:

1. Scalability and its effect on environmental characterization at various scales of process development
2. Methodology for generic and process-specific environmental characterization in coal gasification processing
3. Strategy for projection of commercial-scale process environmental characteristics from sub-commercial-scale data bases
4. Applicability of gasification environmental strategy and data in the analysis of liquefaction systems
5. Methods for generic and process-specific environmental characterization in coal liquefaction processing

To date the bulk of the experience gained in process environment characterization has come from investigations of coal gasification systems. Consequently, gasification experience formed the framework for much of the panel's discussion. One key issue discussed from this context was the extent to which methodology and procedure developed in gasification might have application in liquefaction characterization.

The panel found the issue of scaling to be central to the discussion of all aspects of process environmental characterization, since resources for data base generation are at present limited to pilot plant-scale systems (particularly with respect to medium- and high-Btu systems). The issue of scaling is also expected to persist into the future, however; extended lead times and high costs of coal conversion technology development force early analysis of at least the basic environmental feasibility of processes. Recognizing this fact, the panel considered at some length the question of minimum scales of process development at which meaningful (i.e., scalable) environmental analysis can begin.

What follows is a summary of the various problems and needs identified by the panel relative to each of the major issues listed above.

Relationship of Scalability to the Environmental Characterization of a Process

Scalability of SubCommercial Data Bases

The Problem

PDU and pilot plants are not scale models of commercial-scale facilities, and they are operated over very wide ranges of process conditions, few of which are representative of eventual commercial practice. This raises serious questions regarding the interpretability of environmental data gathered from such units, for example:

1. At what stages of process development can various process-stream environmental characterization data be used to project residuals from commercial-scale facilities?
2. What process-stream data (physical, chemical) must be collected for the scaling of environmental data?
3. What process-variable patterns must be linked to environmental characterization data to insure data scalability and at what stage of process development should such analysis begin?

4. To what extent is an understanding of intrinsic mechanisms of effluent formation and decomposition important to the proper correlation of process variable/effluent production patterns? What types of mechanism studies are needed to provide such information?

5. How should environmental data be analyzed at various scales of observation and on what basis should results be reported?

6. What procedures must be applied to the scaling of subcommercial data for the projection of commercial-scale system performance?

7. At any scale of process development, how can experimental equipment be designed to maximize the scalability of environmental data?

As should be apparent from the above questions, the problem of scalability is basically a technical engineering problem; it has ramifications not only for the interpretation of environmental data which may be generated in existing PDU and pilot-scale equipment, but also for the design of future PDU and pilot-scale equipment for maximum scalable environmental analysis. While panel members agreed that substantial amounts of scalable environmental information can, in principle, be collected from both pilot and PDU-scale process equipment, the present generation of experimental systems was not designed to maximize the scalability of environmental data. At present, it is unclear just what kind and how much scalable environmental information is retrievable from these systems.

State-of-the-Art

Primarily as a result of recent experimental efforts in conjunction with the gasification pilot plant program, some progress has been made in addressing at least some of the questions noted above. Extensive initial evidence from Synthane PDU studies of the existence of sensitive relationships between process conditions and effluent production have now been substantiated at several pilot plants. Limited studies are underway (in conjunction with the DOE gasification development program) to examine the basic dynamics of formation and decomposition of selected effluent constituents during gasification, most notably phenols and NH_3. Some progress is being made in current pilot plant environmental characterization programs to develop procedures for generating and analyzing scalable data. A limited body of valid scalable process environmental characterization data is evolving.

Research Project Needs

Although recent progress is encouraging, major additional efforts are required to advance the understanding and usefulness of the concept of scalability. Priority projects identified by the panel include:

1. Delineation of methodology on a conceptual level to use subcommercial scale process and environmental data to project residuals from commercial-scale processes.
2. Validation of the concept of using subcommercial process and environmental data to project commercial-scale residuals, using current PDU pilot, and anticipated demonstration-scale systems.
3. Development of accurate (± 10 percent) process stream flowrate measurement techniques, e.g., for coal and condensate slurries, raw gases and liquids, which are required to convert measured concentration data to mass production rates.

4. Development of improved sampling techniques for the determination of process variable relationships with selected gas phase environmental parameters, notably:

   - trace metals
   - sulfur species
   - tar particulate loadings and size distribution
   - metal carbonyls (where assumption of chemical form, e.g., $Fe(CO)_5$ and $NI(CO)_4$, are not required)
   - nitrogen species--NH_3, HCN, NO_x, etc.

Defining Basic Scalability Relationships

The Problem

In any process-specific environmental characterization effort, the potential list of process variables which might be screened for effects on effluent production is large. Of the set of possible variables, few are independent, even fewer relate directly to the physico-chemical events which control effluent production. There is need for a formalized development of insight into effluent formation/decomposition phenomena which can form the basis for effective screening of process variables for correlation of environmental data.

State-of-the-Art

Process variables of potential interest fall into three basic categories:

1. Process operating conditions, e.g., reactor temperature, pressure, residence time, partial pressures of constituents (CO_2, H_2O, H_2)
2. Feedstock properties, e.g., coal type, H/C ratio, volatility, mineral content

3. Mechanical properties of system, e.g., reactor geometry (e.g., fluidized, fixed, entrained), mixing characteristics, reactant flow characteristics (e.g., cocurrent, countercurrent)

Process is being made in assessing the relative impact of these groups of process variables on changes in effluent production. Primary contributions are coming in conjunction with efforts to build scalable environmental data bases at DOE gasification pilot plants. Limited fundamental studies are now being funded by both DOE and EPA.

Research Project Needs

The panel identified the following specific projects to contribute needed additional information and tools for the delineation of basic scalability relationships:

1. Development of a generalized process variable model which might guide one in the selection of process variables in process-specific experimental program for the generation of a scalable environmental data base

2. Generation of a sufficient data base to formulate a generalized model of the factors which influence the fate (production, distribution) of nitrogen, sulfur, hydrocarbons, and trace elements in gasification systems. Resources required include bench-scale, PDU-scale, and pilot-scale data

3. Development of guidelines for the determination of optimal sampling strategy (frequency, duration of commposite sampling) necessary for the generation of matched, correlatable process, and environmental data bases

State-of-the-Art

Essentially no data exist in coal gasification systems and only limited development of methodology for evaluating scalability and designing scalable sampling strategy has occurred to date. A substantial industrial hygiene data base is being developed at the SRC liquefaction pilot plant in Tacoma, Washington, but the issue of the nature of its scalability has not yet been addressed.

Research Project Needs

The panel noted a synergism between occupational health data base research needs and development needs outlined earlier in bioassay measurements. Techniques developed there will undoubtedly contribute to improved capabilities for industrial hygiene characterization in process specific applications.

Research needs identified by the panel which relate specifically to subcommercial data base generation include:

1. Development of a methodology for scalably characterizing potential occupational health factors in subcommercial-scale coal conversion systems
2. Evaluation of the relative merits of scalable process streams analysis for PDU and pilot scale screening of potential industrial hygiene-related system leaks
3. Determination of the relative toxicity of primary, scalable effluent-bearing streams in PDU and pilot scale systems
4. Development of a strategy for extrapolating subcommercial-scale occupational health data bases to the projection of probable commercial-scale process characteristics

Implicit in these projects is the assumption that scalable industrial hygiene investigations can be conducted on PDU and/or pilot-scale systems. Although yet to be confirmed by experiment, panel consensus was that the prospects were good.

Generation of Scalable Gasification Effluent Data Bases

Focus and Protocol for Field Sampling Programs

The Problem

The panel identified a need for the delineation of basic methodology for the development of scalable subcommercial-scale data bases which can be used to project reliable environmental characteristics of commercial-scale systems. Methodology developed should address data base generation at all scales of process analysis (bench, PDU, pilot, demonstration) and should be applicable across the range of potential gasification (and hopefully liquefaction) processes.

Major subproblems identified by the panel include:

1. Identification of scalable, environmentally significant process characteristics/streams
2. Development and validation of process-specific sampling and analytical techniques
3. Development of baseline environmental data bases for priority species
4. Closure of critical environmental element material balances notably, S, N, trace elements

These problems must be solved with an overall strategy in mind which addresses the issue of defining relevant functional relationships between process variables and environmental characterization data. Both quantitative and semiquantitative relationships can aid in the interpretation and scaling of data.

State-of-the-Art

The panel spent considerable time attempting to organize and summarize state-of-the-art practices currently being employed in the field for the generation of process-specific environmental data bases. Results of this effort are summarized in Figure 1. General scalability characteristics of various scales of process development systems are sketched in Table VI. Finally, estimates of the stages of process development at which various facets of environmental characterization can be developed are summarized in Table VII.

Project Needs: Subproblem 1

Data base scalability criteria are based on two factors: (1) the relationship of process unit operations/procedures from one scale of operation to the next (e.g., PDU to pilot), and (2) an ability to relate major process variables and effluent production rates for individual process units/scales. For example, the acid gas removal system of the Hygas pilot plant and the once through direct water quenching system at the CO_2-Acceptor pilot plant are not scalable reflections of expected demonstration or commercial-scale practice.

While measurements around such pilot-scale units can prove helpful for the determination of upstream effluent characteristics, environmental characteristics of streams leaving these units do not represent scalable information. In general, scalability increases with the degree of process development. Environmental data from bench-scale equipment is at best qualitative and not scalable. PDU and

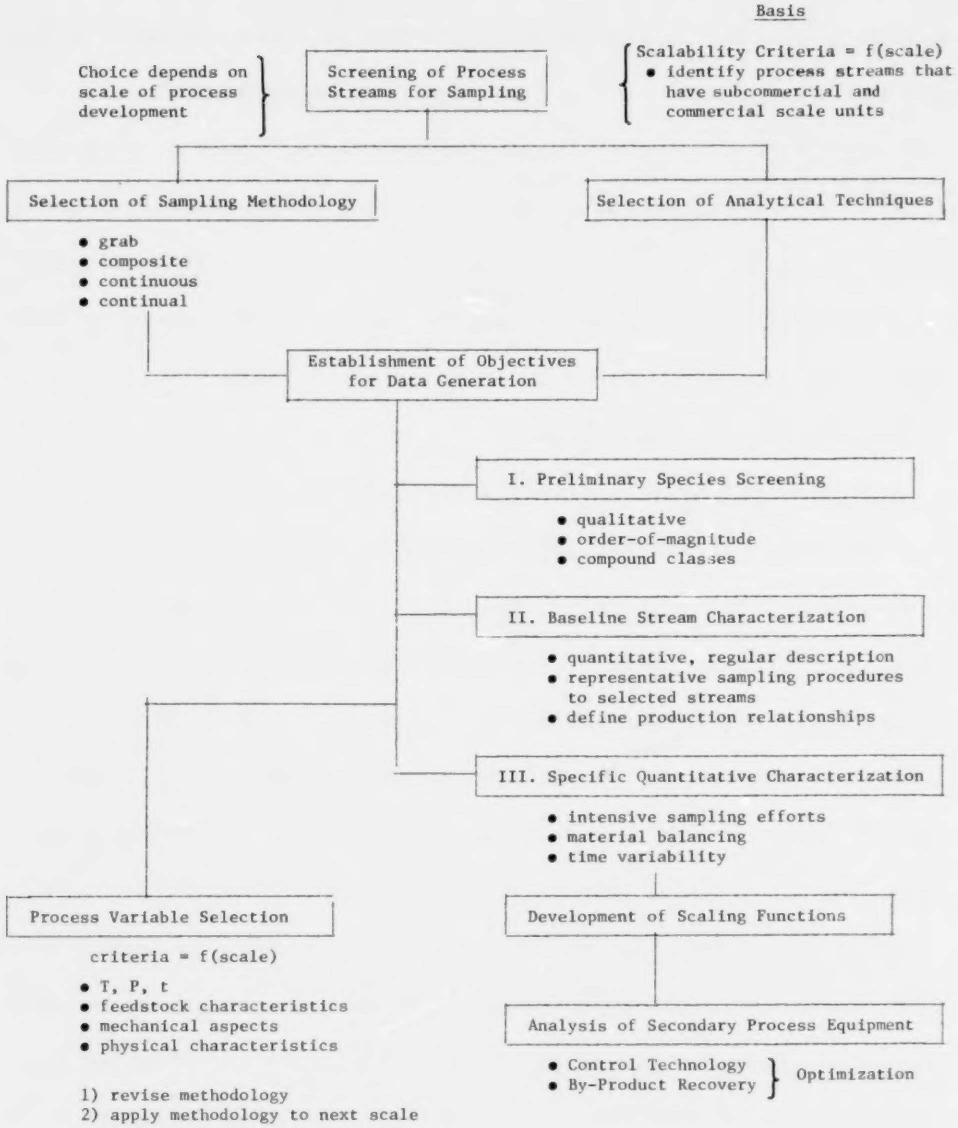
Basis
Choice depends on scale of process development
Screening of Process Streams for Sampling
Scalability Criteria = f(scale)
• identify process streams that have subcommercial and commercial scale units
Selection of Sampling Methodology
• grab
• composite
• continuous
• continual
Selection of Analytical Techniques
Establishment of Objectives for Data Generation
I. Preliminary Species Screening
• qualitative
• order-of-magnitude
• compound classes
II. Baseline Stream Characterization
• quantitative, regular description
• representative sampling procedures to selected streams
• define production relationships
III. Specific Quantitative Characterization
• intensive sampling efforts
• material balancing
• time variability
Process Variable Selection
criteria = f(scale)
• T, P, t
• feedstock characteristics
• mechanical aspects
• physical characteristics
1) revise methodology
2) apply methodology to next scale
Development of Scaling Functions
Analysis of Secondary Process Equipment
• Control Technology
• By-Product Recovery
Optimization

FIGURE 1
GENERIC OUTLINE OF THE BASIC METHODOLOGY INVOLVED IN THE GENERATION OF SCALABLE, SUBCOMMERCIAL BENCH, PDU, PILOT, AND DEMONSTRATION-SCALE ENVIRONMENTAL DATA BASES

TABLE VI

GENERAL SCALABILITY CHARACTERISTICS OF VARIOUS SCALES OF PROCESS DEVELOPMENT SYSTEMS

Scalability Criteria	
Bench:	• batch operation, small throughputs (typically <25 lbs/hr) • trying to determine process feasibility • begin to develop analytical methodology
PDU: (Process Development Unit):	• continuous operation of conversion unit unit (1-5 tons/hr) • concern only to produce desired product • conversion processing product 1) begin to study process variable effects on conversion unit discharge streams (environmental products. 2) only consider conversion reactor discharge streams for scaling of environmental data. 3) begin to develop sampling methodology (i.e., when the sample; how to sample, representativeness of sample). 4) is PDU operating at specified conditions?
Pilot Plant:	• continuous operation of conversion unit plus a partial set of downstream processing systems • conversion processing/treatment polished product 1) begin to apply parametric studies (best data set) must have extended online time (>30 days) is data transferrable to next scale?

TABLE VI (Continued)

Demonstration Scale:	• conceptual, integrated plant layout, single train • operation at optimum operating conditions • scalable process/environmental analysis • installation of required technologies (BPCTA)
Commercial Scale:	• multiple train

TABLE VII

PANEL ESTIMATES OF THE STAGES OF PROCESS DEVELOPMENT AT WHICH VARIOUS FACETS OF ENVIRONMENTAL CHARACTERIZATION CAN BEGIN

Facet of Environmental Characterization	Scale of Process Development Systems[a] Bench	PDU	Pilot	Demo	Commercial
Stream Selection	0	1	2	3	3
Sampling Methodology	0	1	2	3	3
Analytical Methodology	1	2	3	3	3
Preliminary Species Scr.	1	2	3	3	3
Baseline Monitoring	0	1	2	3	3
Specific Characterization	0	1	2	3	3
Control Technology	0	0	1	2	3
Optimization	0	0	0	1	2

(a) Key

0: zero effort

1: initial development

2: hypothesis testing, modification, improvement

3: finalized strategy resolved

pilot plant reactors can be scalable. However, PDU and pilot-scale plant discharges are rarely directly scalable since scaled-down control technology is typically not included in such plants.

Specific needs identified by the panel include:

1. Development of systematic procedures for the review and analysis of bench, PDU, pilot-scale plant configurations/operations
2. Development of systematic procedures for the review and analysis of conceptual commercial designs of processes undergoing subcommercial-scale environmental characterization
3. Development of systematic procedures for the identification/specification of experimental processing units from which various environmental data can be scaled through the application of standard engineering practices

Project Needs: Subproblem 2

Representative sampling and accurate sample characterization are required for the generation of an effective data base. Variations in stream composition with time necessitate time-series analysis; measured character of variation provides the basis for specification of routine grab, composite, or continuous sampling. Sampling of scalable streams often requires the application of high-pressure, high-temperature sampling techniques. Since analysis is often performed offsite, adequate procedures must be available for field preservation of samples. Finally provisions must often be made for analytical biases and/or chemical interferences which occur in complex samples.

Specific recommendations by the panel include:

1. Adoption of time-series sampling and analysis as a routine procedure for analysis of stream variability and the design of effective regular sampling strategies

2. Development and application of procedures for estimating volatile effluent losses during the depressurization of high pressure liquids
3. Improvement of available technology for high-pressure, high-temperature sampling
4. Support for the development and application of quality assurance programs (discussed in detail earlier in this report) in field studies to insure adequate sample preservation and accurate analysis

Project Needs: Subproblem 3

Baseline effluent production characteristics must be expressed in scalable terms and reflect any significant variations which may result from changes in process conditions. This requires (1) patterned sampling across a range of plant operating schedules and (2) application of selected process data, notably stream flow rates and coal feed rates, to the reorganization of effluent concentration data into scalable forms, e.g., pounds of effluent production per ton of moisture, ash-free coal feed. The panel recommends that guidelines be developed for the reporting of environmental data in scalable forms with some consideration for process-induced variability.

Project Needs: Subproblem 4

Although material balances are an essential part of process engineering analysis, routine process development rarely includes accurate material balancing efforts for environmentally significant species, notaly sulfur, nitrogen and trace elements. Material balancing in environmental characterization efforts can provide considerable insight regarding the accuracy and reliability of individual component process and environmental data. However, not all plants are equally amenable to material balance on environmental parameters. The adequacy of sampling techniques and process data availability vary from plant to plant and with the scale of process development. The panel recommended that informal guidelines be developed for the application and interpretation of material balances in environmental characterization at various stages of process development.

Criteria for Prioritization of Characterization Efforts

The Problem

Given limited resources of time and money, the basic problem is how to prioritize sampling and analysis efforts (e.g., process stream and environmental species selection, intensity of sampling, extent of process analysis) to insure that the available effort is expended on the most scalable, environmentally significant aspects of the process. Definition and prioritization criteria are required. These must be readily applied to the development of a phased characterization effort based on the results of an initial screening survey of scalable plant streams. Any such criteria would have to reflect directly on potential health and/or environmental impacts. Some form of bioassay activity would appear to offer the most probable practical basis for the development of a set of useful criteria.

State-of-the-Art

Few criteria of any kind currently exist to aid one in prioritizing field experimental and laboratory support efforts. Criteria pollutants, standard water quality criteria, and identified, regulated effluent parameters in analogous industries (petroleum, by-product coking) serve as the present basis for prioritization in most cases.

TLB's and LD-50's and EPA's multimedia environmental goals (MEG) tables are available for some compounds which might be identified in coal conversion samples. Similarly, bioactivity data and toxicology data are available on selected individual compounds. However, screening identification process streams is prohibitively expensive and time consuming. At the same time, potential synergistic and antagonistic effects of mixtures of material on health and environmental impact are essentially unknown. Some screening tools are being generated by EPA in conjunction with the synthetic fuels program which will provide information on the bioactivity of analytically characterized samples. However, the bioassay techniques involved and the quality of the analytical data may limit the usefulness of the data.

Research Project Needs

The panel recommended two actions be initiated:

1. Development of a set of bioassay procedures with known confidence levels, with an emphasis on reduced probability of false negative responses, and a capability for semi-quantitative characterization of response
2. Evaluation of EPA MEG's through the bioassay characterization of analytically well-defined samples of coal conversion related materials

The combined effect of these two efforts would be both the development of a capability for analysis of complex mixtures, and the assessment of a significant block of potential single component decision criteria based on concentration.

Scalable Fugitive Emissions Characterization

The Problem

Characterization of fugitive emissions in subcommercial-scale equipment can be complicated. Subcommercial-scale equipment and the leaks from them are in many instances nonscalable. Due to widely varying operating conditiions in many test systems, interpreting the scalability of leak composition data can present additional problems. At issue is the stage of process development at which scalable fugitive emission analysis can begin and the procedures which can be applied for meaningful analysis.

Independent of the issue of scaling, there are at present essentially no data available on the nature and extent of possible fugitive emissions from coal conversion processes.

State-of-the-Art

A strategy involving process stream characterization has been proposed for pilot plant fugitive emission studies. It is predicated on the argument that process stream compositions are a good first order qualitative estimate of fugitive emissions, differing only by the extent of any chemical reactions which may occur during or immediately following emission release. Little has been done to develop and/or evaluate the merits of this strategy.

Limited data on fugitive emissions from related industries are available; however, its applicability to coal gasification and liquefaction systems is unknown.

Project Research Needs

The panel identified several needs relative to fugitive emission characterization in coal conversion systems:

1. Investigation of the prospects and strategy for process stream characterization as a technique for fugitive emission analysis
2. Development of screening techniques for the identification and qualification of fugitive emissions and their sources
3. Development of a reliable sampling technique for the determination of fugitive emission rates and compositions in coal conversion systems
4. Development and use of surrogate or "tracer" components

Applicability of Gasification Environmental Strategy and Data in the Analysis of Liquefaction Systems

Coal gasification environmental data, although limited, are considerably more extensive than current liquefaction data. In approaching the issue of liquefaction environmental analysis, the first question the panel asked was: What, if any, extrapolations can be made from measured gasification environmental characteristics to liquefaction systems? While panel members could not come to any specific conclusions during the workshop, there was agreement that at least some meaningful conclusions might be reached through a careful analysis of detailed liquefaction process flowsheets and operating procedures, given the understanding of process variable/effluent interactions presently available from gasification studies.

Generation of Scalable Liquefaction Effluent Data Bases

While substantial amounts of chemical and biological characterization have been conducted on samples drawn from liquefaction systems, the focus of essentially all such work has been analytical development and basic environmental screening, not scalable process characterization. There has as yet been no initiation of process environmental characteriation activities comparable to the major scalable efforts underway in the gasification pilot plant program. As a consequence, there is not a wealth of direct experience upon which to draw specific conclusions regarding issues/problems and needed project activity for scalable process environmental characterization of liquefaction systems. The panel did conjecture that gasification environmental characterization methodologies in use and outlined earlier in this report could in general be applied successfully to liquefaction systems. The issue of scaling and its significance in liquefaction environmental characterization was discussed; however, in lieu of any available coupled process and environmental data, the issue could not be resolved.

Initiation of Scalably Directed Process Specific Programs

The panel recommended two research projects to initiate process environmental analysis of coal liquefaction systems.

1. Review existing liquefaction environmental data and correlate it against process variables to the extent possible with the objectives of:
    - Providing a basis for a quantitative analysis of the strengths, weaknesses, and inadequacies of the current data base
    - Illustrating any evidence of relationships between process conditions and effluent production rates

It is anticipated that the results of this effort would serve as a reference point for the delineation of future program efforts.

2. Develop new site-specific field environmental programs designed to generate scalable data on major and trace environmental species in relation to the operating characteristics of liquefaction systems

Such programs should be designed first to establish those process data needed for proper interpretation of variable environmental data, and then to utilize the results for the construction of a comprehensive, scalable environmental data base.

Management of Liquefaction Environmental Characterization Activities

Reflecting a pattern set in the coal gasification pilot plant environmental characterization program, the panel recommended the establishment of a series of site-specific environmental teams chartered to develop meaningful environmental data bases at each of the major liquefaction pilot plants. Also considered was the potential value of one or more oversight teams charted to coordinate and integrate various environmental characterization activities and results across the range of ongoing liquefaction projects. A comparable coordination systems is currently in place in the gasification program. No conclusion was reached by the panel.

Delineation of Basic Process Variable/Effluent Production Relationships

As an aid to the design and analysis of field sampling efforts, the panel recommended consideration of one or more laboratory or PUD-scale experimental programs directed to an analysis of basic process variable/effluent production relationshiips in liquefaction processing. Particular emphasis should be placed on the analysis of any significant sensitivity of liquefaction catalyst interactions with effluent production rates.

Projection of Commerical-Scale Process Environmental Characteristics

The Problem

Projection of commercial-scale environmental characteristics requires a data base structured to accommodate changes in such characteristics which result from changes in feedstocks and process conditions occurring during process scaleup. At present there are only limited data on gas, liquid, or solid phase environmental characteristics which could be used to accurately project process specific commercial-scale process environmental characteristics.

Needs in gas characterization include composition, production rate, and bioassay activity of raw product gas and fugitive emissions. Each element of data should be accompanied by adequate definition of process operating conditions to allow evaluation of relationships between process operations, potential airborne emission releases and the application of those relationships to the use of the data. Environmental parameters of interest include particulate loading, particulate size distribution and composition, fixed gases, ammonia, hydrogen cyanide, sulfur species (H_2S, COS, CS_2, SO_2, mercaptans), trace elements (particularly those of greatest environmental concern), and the set of environmental parameters necessary for determination of the treatability of aqueous and hydrocarbon condensates. Each element of data should be accompanied by adequate definition of process-operating conditions to allow evaluation and use of any relationships in the scaling of the environmental data.

Needs in solids characterization include data on the leachability of trace elements, the presence and composition of organics, and bioassay activity. Data must be collected on scalable solids under conditions which simulate those expected in potential disposal sites.

Given adequately comprehensive PDU and pilot-scale data bases on environmental characteristics of gas, liquid, and solid effluent streams, there remains the question of interpreting and scaling such data for use in the projection of commercial-plant environmental characteristics.

Proposed Research Projects

Although the science of data scaling is a fundamental and well-developed facet of process engineering, it has yet to be applied in any sophisticated way to the projection of process environmental characteristics. The panel recommended:

1. Development and documentation of appropriate methodology for analyzing differences between experimental and commercial-scale equipment design and cooperating conditions as they bear on the production and distribution of effluents
2. Formulation of engineering guidelines for the scaling of PDU and pilot-scale data for purposes of projecting commercial-scale process environmental characteristics

CONTROL TECHNOLOGY MEASUREMENTS: TREATABILITY AND PERFORMANCE

Issues of control technology measurement were divided into four categories for discussion:

1. Applicability of analogous industry treatability experience, e.g., petroleum, by-product coking
2. Gas purification and treatment
3. Wastewater handling
4. Solid waste handling

The panel recognized that these areas overlap. However, depending upon the type of product to be produced from a coal conversion process, one medium generally presents more challenging and unsolved problems than the other medium. For example, in high-BTU gasification, successful management depends heavily on proper handling of aqueous effluents. By contrast, comparatively little wastewater is produced in low-BTU gasification; there, attention is directed toward gas purification and solid waste disposal.

What follows is a review of panel discussion regarding the critical issues, states of the art, and research needs associated with control technology analysis in coal conversion. Since the state of development of the coal conversion field is at present largely PDU and pilot in scale, control technology discussions are developed primarily in that context. As such, studies of control technology are assumed to be divorced from process studies, since few PDU or pilot-scale coal conversion systems are equipped with scalable control equipment.

Relevance of Analogous Industry Treatability Experience

Problem

There is a substantial body of commercial experience on the performance of a variety of gas, liquid, and solid treatment systems in industries considered to be similar to coal conversion, notably petroleum refining and by-product coking. In the absence of direct data on the performance of these systems on coal conversion wastes, their treatability is often assumed in the analysis of process commercial-scale projection. There is a need for delineation of the major strengths and weaknesses of such arguments by analogy, since they presently constitute a significant basis for the projection of anticipated commercial-scale process environmental impacts.

Gas Purification and Treatment

Important issues in this category include prediction of commercial-scale raw quenched product gas composition from pilot plant data, specification of commercial-scale effluent streams and estimation of the composition of these streams, and assessment of the fate of trace constituents.

Prediction of Quenched Product Gas Composition

The Problem

Most PDU and pilot-scale coal conversion systems are not equipped with scalable raw product gas quenching systems. As a result, measured quenched product gas compositions are typically not representative of commercial-scale compositions which would be introduced into a gas purification system. It is therefore necessary to be able to correct measured gas compositions to properly reflect commercial-scale conditions.

State-of-the-Art

Thermodynamic models are available for calculation of equilibrium distribution of components between gas and water in the quench tower. However, (1) appropriate parameters to address the complex, nonideal solutions involved are only partially available, and (2) little information is available on the distribution coefficients for most of the trace effluent species of greatest environmental significance (e.g., HCN and organics). Although some design groups have addressed these problems, their results remain essentially proprietary and therefore unavailable for careful scouting and widespread distribution.

Need

Panel members identified a need for organization of basic data and models appropriate for the meaningful characterization of the distribution of complex raw gas mixtures in commercial-scale quench systems, given PDU and pilot-scale data bases. Not all of the thermodynamic data needed for proper modeling characterization are available over the desired range of system temperatures, pressures and gas compositions. For example, flash equilibrium distribution data (K values) are not only a function of system pressure and temperature, but also depend upon raw gas composition. Experimental determination of sensitivities is important to an assessment of critical data needs.

It is recognized that state-of-the-art gas quenching is practiced at several commercial-scale facilities, e.g, Lurgi, Koppers-Totzek. Selected quench systems should be evaluated experimentally both as a source of needed data and as a basis for evaluating the effectiveness of available models.

Specification of Major Gas Purification Effluent Streams

The Problem

The fate of major gas constituents in gas purification is well-known; however, little if any data are available on the fate of minor and trace organic and inorganic environmentally significant species, e.g., HCN, NH_3, COS, C_1-C_6 HC's, and heavy organics. Although several commercially attractive gas purification systems are available for application in coal gas cleaning, presently the effectiveness of these systems can be determined only through fairly detailed engineering design analysis.

Need

Experimental analysis of the fate of important minor and trace organic and inorganic species is needed in commercially attractive gas purification systems. Systematic sampling programs should be implemented in those coal conversion pilot plants which are equipped with scalable gas cleanup systems, e.g., Bi-Gas (Selexol treatment system), Combustion Engineering (Stretford system). Particular effort should be made to determine the extent to which trace metals may accumulate in process sludges.

Characteristics of commercially attractive gas purification systems and the fates of environmental species need to be assembled in an organized manner for convenient access and use in the projection of commercial-scale process environmental impact. Information should be organized in such a manner that major process engineering analysis is not required, to establish the bulk fate of various environmental species in the processing of a particular raw gas.

Wastewater Treatment

Important issues in this category include identification of effluent flow rates and composition, development of a water management strategy, evaluation of water management systems, and determination of the fate of trace metals and trace organic compounds in aqueous effluents.

Identification of Effluent Flowrates and Compositions

The Problem

Raw process aqueous condensates produced in PDU and pilot-scale coal conversion systems must be evaluated carefully, in relation to commercially significant flow rate and composition. For reasons discussed previously in gas treatment, PDU and pilot scale quench systems typically do not distribute gas constituents to the water as would occur commercially; quench condensate flows are also typically not representative of commercial-scale flow rates.

The Need

Just as quenching systems must be studied to estimate raw quenched gas composition so must these systems be studied and the results used to predict correct mass discharge and volumetric flow rates. Pilot plant quench condensates data bases may be biased by several factors including (1) the addition of dilution water, (2) the use of quenching temperatures and stages different from those of the commercial design, and (3) the use of different steam-to-coal ratios at the pilot plant than are envisioned for the commercial process.

Issues related to the scalability or representativeness of pilot plant aqueous effluents have not received detailed evaluation. These issues must be carefully evaluated to determine the extent to which various measured wastewater characteristics reflect or do not reflect their commercial-scale counterparts. While the procedures for characterizing the representativeness of a wastewater and/or the requirements for alteration to make it representative of its commercial counterpart are known, they are not effectively outlined and generally available for use by those involved in wastewater analysis and projection.

Development of Wastewater Management Strategy

The Problem

Broad analysis of aqueous effluent treatment and control systems is complicated by the fact that there are a variety of alternative means to accomplish heat and water balances in coal conversion systems. Also, for any given strategy there are a variety of competing unit operations which may be employed to treat aqueous effluents to desired quality levels. Because of the complex interaction between heat and material balances, there are no obvious optimal pathways. The analysis of this problem from a broad viewpoint of defining water sources and uses requires strong insights with regard to water availability, water consumption, and production rates, and the basic feasibility of alternative processing schemes.

The Need

Various design firms have prepared heat and water balances for proposed facilities. Unfortunately these designs have been presented without description of the design intent or discussion of alternatives. Design intent must be clarified for these existing proposed systems and be made a requisite part of future design studies. This will permit a clear definition of critical issues as envisioned by the designer. Such an explicit statement of strategy should also serve to identify preconceived constraints and biases associated with the design.

A general systematic approach is needed to help define critical issues and problems related to water use and management in coal gasification systems. This is necessary in order to maximize benefits from increases in process efficiency and reduction in water consumption.

Evaluation of Water Management Systems

The Problem

Water management systems for processing raw feed water to a gasification facility can be designed using state-of-the-art technology. These systems can be designed without the need for detailed experimentation on the basis of substantial industrial experience with the treatment of raw surface and ground waters for process use.

The situation is quite different with regard to design of units for the treatment of process wastewaters for recycle and reuse as feed water. At present there exist only limited experiences with the processing of any commercial or pilot plant effluents for this use. Processing experience at commercial gasification facilities is limited because these facilities have not been faced with the strict environmental controls and minimum water consumption requirements which promote consideration of wastewater recycle/reuse. There is also a lack of detailed design information for recycle/reuse processing of aqueous effluents in commercial coke plant operations. Hence, there is, even in the broadest respects, only general qualitative design information available at present on this issue.

The Need

There is a need to identify and establish minimum water quality requirements for process water reuse. This is necessary in order to be able to specify minimum process water treatment requirements. Generally, water quality requirements are known for the manufacture of steam; however, it is not generally known the degree to which some limits or restrictions can be compromised. There may be insufficient data for selected compounds (e.g., SCN^-) peculiar to coal conversion effluents.

Minimum water quality requirements for cooling towers are not well understood and must be established. Operating problems and costs have not been summarized which describe industrial experience in the use of minimally treated wastewaters for cooling tower makeup. It is important to understand tradeoff between increased cooling tower operating costs and additional capital and operating costs for further treatment of wastewater destined for use in cooling towers. Cooling tower makeup water quality at proposed facilities has varied from stripped dephenolated wastewater, to biologically treated wastewater, to wastewater evaporative condensate.

The state-of-the-art for many wastewater treatment systems is undefined and experimentation is required. Important issues are outlined below. Biological treatment by activated sludge and trickling filter has been demonstrated only on a limited basis. Many process effluents have not been subjected to systematic evaluation of specific biological treatability characteristics. The use of oxygen, and activated carbon or coal char in activated sludge has been proposed, but not evaluated. It may be that the use of oxygen is warranted only if there is a large oxygen plant in support of the gasification processes. For these and other issues, related industrial processing information is not especially useful other than to identify potential problems and to indicate which treatement processes have achieved commercialization. Anaerobic treatment, or combinations of biological treatment systems, have not been demonstrated. Problems associated with disposal of biological and other wastewater treatment sludge are unknown. There is no information on fate of trace metals or trace organics during wastewater processing of coal gasification wastewaters. Screening studies are now in progress but only at a few locations.

There has been no experimental evaluation of water reuse strategies. It is suspected that industrial research for commercial purification processes may be fairly complete, but the data are proprietary. A few bench-scale studies are in progress. The methodology of wastewater treatment experimentation needs to be articulated in order that these experiments yield useful, scalable data. The studies should be configured to produce conventional design expressions for removal of primary pollutants as well as to show the fate of trace organic and inorganic species.

Solid Waste Management

The Problem

The basic issue surrounding solid waste management in coal conversion relates to the direct and/or indirect environmental impact of its disposal. The major solid of potential impact is coal ash; secondary although potentially significant additional solids include wastewater treatment sludges, spent catalysts, and miscellaneous process solids.

In the spirit of the recent Resource Conservation and Recovery Act, analysis of the impact of representative coal conversion waste solids is required. At present evidence pointing to the presence or absence of any potential problems is limited, both by the availability of representative materials and by the availability of a tested, accepted screening procedure. It is recognized that the EPA and ASTM have proposed standard solids leaching test procedures, but these procedures were proposed out of expediency, and they need to be evaluated to determine their effectiveness on coal conversion wastes.

The Need

Well-referenced standard test procedure for the analysis of potential environmental impacts of solid waste disposal must be developed. The test procedure must reflect concern for pertinent chemical and physical leaching conditions as they may affect the migration of organic and inorganic species. These conditions must relate in some fashion to geological formation effects, so that laboratory screening test data can be expected to model conditions which may reasonably be expected to exist at a disposal site.

If it is found that residual solids pose any identifiable environmental hazard, steps can be taken on the basis of the data to formulate strategy for treatment.

APPENDIX A

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WORKSHOP ON THE HEALTH AND ENVIRONMENTAL EFFECTS OF COAL CONVERSION TECHNOLOGIES

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REPORT NUMBER	TITLE	NTIS REPORT NUMBER	NTIS PAPER COPY COST (at time of submission)
DOE/HEW/EPA-01	Health and Environmental Effects of Coal Gasification and Liquefaction Technologies. Background Material for a Workshop.	PB 296 708	$10.75
DOE/HEW/EPA-02	Health and Environmental Effects of Oil Shale Technology. A Workshop Summary and Panel Reports	PB 297 096	$10.75
DOE/HEW/EPA-03	Health and Environmental Effects of Coal Gasification and Liquefaction Technologies. A Workshop Summary and Panel Reports	To be submitted during week of July 23, 1979	
DOE/HEW/EPA-04	Coal Technologies. Background Information on Processes and Pollutants	To be submitted during August 1979	

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